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INDEX

Page

Ablation in the Scottish Highlands ... 292
Africa, Hailstones encountered by aircraft near Lake Victoria, east 178
Ahlmann, Hans W : son; The present climatic fluctuation 14
Air motion ahead of warm fronts ... 86
Aircraft soundings of temperature and frost point, Simultaneous 355
– struck by lightning 121
Aldis, V. R.; Australian drought cycles 361
Altocumulus castellatus at Farnborough 177
– – clouds 266
Altocumulus, Clear lane cut by aircraft in 153
Analysis in forecasting, The significance of three-dimensional weather... ... 50
– in the Mediterranean, Upper frontal... 191
Anomalous radio propagation 74
April 25–26, 1950, Snowstorm during the night of... 224
Antarctic, Weather information from British whalers in the 299
April, Unusually cold upper air temperature for 328
Astronomical Society, Royal 55, 353
Atlantic, Recent long period with pressure above normal over Europe and the North 129
Atmosphere, Oscillations of the earth's 90
–, The general circulation of the ... 175
Atmospheric turbulence 90
August 1947, Absolute droughts of ... 260
Austin, E. E.; Climatology (review) ... 238
Australian drought cycles 361
Aviation meteorology of the route Castel Benito–Cairo 151
– – – – – Marseilles–Castel Benito ... 87

Band—a phenomenon associated with radar echoes from falling rain, The bright 151
Bannon, J. K.; Shear frequencies in the upper troposphere and lower stratosphere over England 161
Beck, Mr. and Mrs. J. B. 155
Belasco, J. E.; Lightning display at Ramsgate 25
Berg, H.; Grundfragen der Wetterkunde 301
Bergeron, T.; Tropical hurricanes ... 265
Best, A. C.; Atmospheric turbulence (review)... 90
–; On the formation of drops in clouds and fog (review) 270
Bilham, E. G.; New version of the humidity slide-rule 65
– humidity slide-rule, Mk. III 25
Bishop Shield Competition 305
Books received ... 29, 210, 242, 332, 361
Botley, C. M.; Rainbow without visible precipitation 298
Brierley, J. M.; Extremes of humidity ... 120
Briggs, J.; Notes on the temperature at which radiation fog forms 343
British Rainfall 1940–42... 56
– – 1948 324

Page

British Thunderstorms 1949, May 14–16 28
Britton, C. E.; A chronology of British weather... 329
Brock, D. S.; Cambridge University Iceland expendition of 1947 219
Brooks, C. E. P.; Cloud phenomenon near Ferring, Sussex, May 14, 1950 ... 266
–; Das Klima der Vorzeit (review) ... 331
–; Legacy of the ice age 321
–; Relation between number of days with 0·4 in. or more of rain and total rainfall 152
Bull, G. A.; Electric charges on rime-covered surfaces (review) 207
–; Grundfragen der Wetterkunde (review) 301
–; The climate of the Netherlands (review) 180
–; The thunderstorm—Report of the thunderstorm project (review) ... 268
Burgess, C. R.; Meteorology for seamen 271
Burnet, A.... 304

Cambridge University Iceland expedition of 1947 219
Carruthers, N.; Regression of climatic elements on latitude, longitude and elevation in India (review) 122
Challenger Society, Meeting of the ... 204
Champion, D. L.; Ablation in the Scottish Highlands 292
–; Winter gales and Hebridean shipping 340
Charles Chree Memorial Lecture ... 56
Chronology of British weather 329
Climate of the Netherlands, The ... 180
Climates of Addu Atoll, Agalega Islands and Tristan da Cunha, The 173
Climatic change 176
– elements on latitude, longitude and elevation in India, Regression of 122
– fluctuation, The present 14
– trend, Recent 189
Climatological table for the British Commonwealth, Monthly 179
– tables for the British Commonwealth from July–December 1949 ... *monthly*
Climatology 238
Cloud and precipitation, The physics of 173
– Atlas, Photographs for new International... 26
– funnel of waterspout, Flight through... 24
– phenomenon near Ferring, Sussex, May 14, 1950 266
–, Pilot-balloon ascent near cumulonimbus 327
– which did not extend to the freezing level, Tropical rainfall from 237, 354
Clouds, Altocumulus castellatus ... 266
–, Artificial nucleation of 5
–, Luminous night 87
–, Noctilucent 301
– and fog, on the formation of drops in 270
Coagulation elements in cumulonimbus, The composition of 86
Cold upper air temperature for April, Unusually 328

Page

Conversion of percentage frequencies of fog and of sleet or snow to days per month, at sea 140
Coode, W. M. 61
Courshee, R. J.; Frequency of wind and radiation frosts... 235
Craddock, J. M. and Pritchard, D.; Use of the nodograph in estimating the rainfall at fronts 288
Crichton, J.; Eskdalemuir Observatory 336
Cumulonimbus cloud, Pilot-balloon ascent near 327
– –, Radio-sonde ascent into 23
–, The composition of coagulation elements in 86

Davies, D. A.; Tropical rainfall from cloud which did not extend to the freezing level 354
Day, Variations in the length of the ... 353
De-icing team, Visit of 330
Dewar, D.; Frequencies of tropopause temperature over Larkhill, June 1945 –December 1947 27
–; Preparation of linear-function tables on a Hollerith tabulating machine ... 137
Dobson, G. M. B.; Luminous night clouds 87
Douglas, C. K. M.; Altocumulus castellatus clouds 266
–; Photographs for new International Cloud Atlas 26
Drops in clouds and fog, Formation of 270
Drought cycles, Australian 361
Droughts of August 1947, Absolute ... 260

Eastwood, A. 61
Energy exchanges between the sea and the atmosphere... 55
Eldridge, R. H.; Altocumulus castellatus at Farnborough 177
–; Pilot-balloon ascent near cumulonimbus cloud 327
Electric charges on rime-covered surfaces 207
England, Shear frequencies in the upper troposphere and lower stratosphere over 161
Erratum 49, 91, 333
Eskdalemuir Observatory 337
Europe and the North Atlantic, Recent long period with pressure above normal over 129
Evans, G. J.; Weather Lore (review) ... 302
Extremes of humidity 120
Farnborough, Altocumulus castellatus at 177
Ferring, Sussex, May 14, 1950, Cloud phenomenon near 266
Fog formation, Method of forecasting the temperature of... 213
– forms, Notes on the temperature at which radiation 343
–, Formation of drops in clouds and ... 270
– or low stratus, Method for forecasting time of clearance of radiation... ... 102
Forecasting, The significance of three-dimensional weather analysis in ... 50
Forecasting, The temperature of fog formation 213
– – time of clearance of radiation fog or low stratus, Method for 102
Forrest, J. S.; Variations of thunderstorm severity in Great Britain 233
Fox, Sir Cyril S.; The geology of water supply 153
Frankcom, C. E. N.; Meeting of the Challenger Society 204
–; Meteorological occasion at the Honourable Company of Master Mariners ... 89
Freetown, Diurnal variation of upper wind at 133
Frith, R.; Artificial nucleation of clouds 5
Fronts, Air motion ahead of warm ... 86
–, Use of the hodograph in estimating the rainfall at 288
Frost point, Simultaneous aircraft soundings of temperature and 355
Frosts during spring in Kent, Frequency of radiation and wind... 42
–, Frequency of wind and radiation ... 235

Gales and Hebridean shipping, Winter... 340
Galloway, J. L.; The significance of three-dimensional weather analysis in forecasting 50
Geochimica et Cosmochimica Acta 359
Geology of water supply, The 153
Geophysical prospecting below the bed of the deep sea... 29
– series, New Indian 179
Geostrophic wind with potential temperature, with application to vertical cross-section diagrams, Variation of 97
Germany, Whirlwind near Walsrode ... 267
Gibbs, W. J.; Meteorology at Heard and Macquarie Islands 168
Glasspoole, J.; Australian drought cycles (review)... 361
–; Average annual rainfall over Great Britain 56
– The geology of water supply (review) 153
–; and Rowsell, H.; Absolute droughts of August 1947 260
Gold, E.; Definition of relative humidity 58
–; Frequency distribution of wind speed in synoptic reports 22
Golde, R. H.; "Sferics" and the lightning discharge 277
–; The flight of thunderbolts (review) ... 359
Gordon, A. H.; Royal Astronomical Society 55
—; Temperature and humidity lapse rates near the ocean surface... ... 141
–; Variation of wind with height at low levels over the sea 295
Great Britain, Variations of thunderstorm severity in 233
Groves Memorial Award and Prize ... 330

Hailstones encountered by aircraft near Lake Victoria, east Africa 178
Harper, W. G.; Lerwick Observatory ... 309
Harris, F. J.; Long periods with sunshine every day at Newquay 121

Page
Hay, R. F. M.; Rainfall in east Scotland in relation to the synoptic situation ... 118
Headwinds—Application to air-route planning, Equivalent 298
- on some of the principal air routes, Equivalent 298
Heard and Macquarie Islands, Meteorology at 168
Hebridean shipping, Winter gales and... 340
Hemens, L. G.; Whirlwind at Shoeburyness 256
Hodograph in estimating the rainfall at fronts, Use of 288
-, Movement of jet streams and the wind 357
Hogg, W. H.; Diurnal variation of upper wind at Freetown 133
-; Frequency of wind and radiation frosts 235
-; - - radiation and wind frosts during spring in Kent 42
Hollerith tabulating machine, Preparation of linear-function tables on a ... 137
Hooper, J. E. N. and Kippax, A. A.; The bright band—a phenomenon associated with radar echoes from falling rain ... 151
Humidity, Definition of relative ... 58
-, Extremes of 120
- lapse rates near the ocean surface, Temperature and 141
-, Low 326
- slide-rule, Mk. III, The Bilham ... 25
- -, New version of the 65
Humphreys, W. J.; 182
Hurricanes, Tropical 265

Ice accretion 348
- age, Legacy of the 321
Iceland expedition of 1947, Cambridge University 219
- - - -, Oxford University 222
India, Regression of climatic elements on latitude, longitude and elevation in ... 122
Information from British Whalers in the Antarctic, Weather 299
Inglis, G. A.; Temperature rise on clear mornings 236
Inwards, R.; Weather lore 302
International exchange of views on the operation of ocean weather ships ... 358
- operation of an ocean weather station 359
Inversion, A case of strong turbulence under an 346

Jagannathan, P.; Regression of climatic elements on latitude, longitude and elevation in India 122
Jefferson, G. J.; Method for forecasting time of radiation fog or low stratus ... 102
-; Temperature rise on clear mornings...33, 236
Jeffery, R. W.; A chronology of British weather... 329
Jeffrey, G. A.; Radio-sonde ascent into cumulonimbus cloud 23
Jet streams and the wind hodograph, The movement of 357
Johnson, N. K.; Obituary notice of H. N. Warren 303

Page
Jones, R. F.; Radar echoes from smoke... 89
-; - weather echoes ... 109, 143, 170, 198
Jowett, C.; Slotted sunshine recorder ... 299

Kendrew, W. G.; Climatology 238
Kinshott, E. J.; Unusual fall of rain at Upavon on November 4, 1949 ... 205
Kippax, A. A. and Hooper, J. E. N.; The bright band—a phenomenon associated with radar echoes from falling rain 150
Klima der Vorzeit, Das 331
Knighting, E.; Elements of anomalous radio propagation 74
Kramer, C.; Electric charges on rime-covered surfaces 207

Labrijn, A.; Climate of the Netherlands 180
Lake Victoria, east Africa, Hailstones encountered by aircraft near 178
Lamb, H. H.; Tornadoes of May 21, 1950 245
-; Types and spells of weather in the British Isles 263
Laplace, Loss of the French o.w.s. ... 300
Larkhill, June 1945–December 1947, Frequencies of tropopause temperatures over 27
Legacy of the ice age 321
Lerwick Observatory 309
Lewis, L. F.; Recent climatic trend ... 189
Lightning, Aircraft struck by 121
Lightning discharge, "Sferics" and the... 277
- display at Ramsgate 25
Linear-function tables on a Hollerith tabulating machine, Preparation of... 137
London, Sea breeze across 165
Lore, Weather 302
Ludlam, F. H.; The composition of coagulation elements in cumulonimbus 86
Lumb, F. E.; Upper frontal analysis in the Mediterranean 191
Luminous night clouds 87
Lunson, E. A.; Sandstorms on the northern coasts of Libya and Egypt ... 263

Macquarie Islands, Meteorology at Heard and 68
Manual of meteorological statistics ... 150
Marsh, A. C. 272
Marshall, W. A. L.; Sea breeze across London... 165
Master Mariners, Meteorological Occasion at the Honourable Company of... 89
Matthewman, A. G.; Variation of geostrophic wind with potential temperature with application to vertical cross-section diagrams 97
McVittie, G. C.; Oscillations of the earth's atmosphere (review) 90
Mediterranean, Upper frontal analysis in the 191
Meteorological occasion at the Honourable Company of Master Mariners ... 89
- Office, Annual Report of the 297
- - Discussion ... 14, 50, 81, 112, 146, 348

Page
Meteorological Office News 91, 123, 155, 182, 208, 240, 272, 304, 333, 361
- Research Committee 54, 86, 118, 149, 200, 233, 262 323, 352
- Society, Royal 18, 86, 119, 151, 173, 201, 233, 263, 352
- - and Institute of Physics, Royal ... 119
Meteorology and the community ... 203
- at Heard and Macquarie Islands ... 168
- for seamen 271
-, Universal Decimal Classification 551.5 59, 88
Method for recording synoptic data 11
- of forecasting the temperature of fog formation 213
Miles, M. K.; Air motion ahead of warm fronts 86
Mill, H. R. 180
Morris-Bower, S.; Recent work of the Thunderstorm Census Organization... 233
Murray, R.; Unusually cold upper air temperature for April 328

Needham, G.; Low humidity 326
Negretti & Zambra, Centenary of ... 286
Netherlands, The climate of the ... 180
Neumann, J. and Schwarz, U.; A case of strong turbulence under an inversion 346
Newnham, E. V.; Conversion of percentage frequencies of fog and of sleet or snow to days per month at sea ... 140
-; Recent long period with pressure above normal over Europe and the North Atlantic 129
-; Relation between the average monthly rainfall and average number of days per month with 0·4 in. or more ... 12
-; The climates of Addu Atoll, Agalega Islands and Tristan da Cunha ... 173
Newquay, Long periods with sunshine every day at 121
News in brief 61, 210
Noctilucent clouds on the night of June 30–July 1, 1950 301
Nucleation of clouds, Artificial 5

O.W.S. *Laplace*, Loss of the French ... 300
OBITUARIES
  Beck, Mr. and Mrs. J. B. 155
  Burnett, A. 304
  Coode, W. M. 61
  Eastwood, A. 61
  Humphreys, W. J. 182
  Marsh, A. C. 272
  Mill, H. R. 180
  Warren, H. N. 272, 303
Observatory, Eskdalemuir 337
-, Lerwick... 309
Ocean weather ships, International exchange of views on the operation of ... 358
- - station, International, operation of an 359
- - - JIG—a joint Anglo-Dutch station 206
Official publications 21, 56, 87, 118, 149, 172, 263, 297, 324
Orkney windmill 356
Oscillations of the earth's atmosphere ... 90
Oxford University Iceland expedition of 1947 222
Ozone observations 304

Past, Dr. Ir. J.; Statistisch Onderzock naar de Samenhang Tussen het weer, de Grasproductie, en de Melkaanvoer 154
Paton, J.; Luminous night clouds ... 87
Phillips, P. E.; Flight through cloud funnel of waterspout 24
Physical Society 56
Physics, Royal Meteorological Society and Institute of 119
Pilot-balloon ascent near cumulonimbus cloud 327
Pollution, May 1950, U.S. conference on air 324
Possible effects of heavy rain on aircraft 150
Prediction diagram for radiation fog ... 150
Pressure above normal over Europe and the North Atlantic 129
Pressure-pattern flying, Theoretical aspects of 21
Pritchard, D. and Craddock, J. M.; Use of the hodograph in estimating the rainfall at fronts 288

Radar echoes from falling rain, The bright band—a phenomenon associated with 150
- - - smoke 89, 207
- weather echoes... ... 109, 143, 170, 198
Radiation and its effect on the tropopause and lower stratosphere 201
- - wind frosts during spring in Kent, Frequency of 42
- frosts, Frequency of wind and ... 235
Radio propagation, Elements of anomalous 74
Radio-sonde ascent into cumulonimbus cloud 23
Rain and total rainfall, Relation between number of days with 0·4 in. or more of 152
-, Artificial stimulation of 9
- at Upavon on November 4, 1949, Unusual fall of... 205
Rainbow without visible precipitation... 298
Rainfall 1940–42, *British* 56
- 1948, *British* 324
- and the average number of days per month with 0·4 in. or more, Relations between the average monthly ... 12
- at front, Use of the hodograph in estimating the 288
- from cloud which did not extend to the freezing level, Tropical 237
- in east Scotland in relation to the synoptic situation 118
- over Great Britain, Average annual ... 56
- tables from Nov. 1949 to Oct. 1950 *monthly*
Ramsgate, Lightning display at... ... 25
Recorder, Slotted sunshine 299
Reid, R.; Meteorology for seamen (review)... 271

Page

REVIEWS:
  Aldis, V. R.; Australian drought cycles. J. Glasspoole 361
  Berg, H.; Grundfragen der Wetterkunde. G. A. Bull 301
  Burgess, C. R.; Meteorology for seamen. R. Reid 271
  Fox, Sir Cyril S.; The geology of water supply. J. Glasspoole ... 153
  Inwards, R.; Weather lore. G. J. Evans 302
  Jagannathan, P.; Regression of climatic elements on latitude, longitude and elevation in India. N. Carruthers 122
  Kendrew, W. G.; Climatology. E. E. Austin 238
  Kramer, C.; Electric charges on rime-covered surfaces. G. A. Bull ... 207
  Labrijn, A.; The climate of the Netherlands. G. A. Bull 180
  Past, Dr. Ir. J.; Statistisch Onderzock naar de Samenhang Tussen het weer, de Grasproductie, en de Melkaanvoer. L. P. Smith ... 154
  Schonland, B. F. J.; The flight of thunderbolts. R. H. Golde ... 359
  Schwarzbach, M.; Das Klima der Vorzeit. C. E. P. Brooks 331
  Sutton, O. G.; Atmospheric turbulence. A. C. Best 90
  United States Weather Bureau. The thunderstorm—report of the thunderstorm project. G. A. Bull ... 268
  Vierhout, R. R.; On the formation of drops in clouds and fog. A. C. Best 270
  Wilkes, M. V.; Oscillations of the earth's atmosphere. G. C. McVittie 90
Rime-covered surfaces, Electric charges on 207
Rowsell, H. and Glasspoole, J.; Absolute droughts of August 1947 260

Sandstorms on the northern coasts of Libya and Egypt 263
Saunders, W. E.; Method of forecasting the temperature of fog formation ... 213
Sawyer, J. S.; Equivalent headwinds—application of upper wind statistics to air-route planning 298
–; Formation of secondary depressions in relation to the thickness pattern ... 1
–; Possible effects of heavy rain on aircraft 150
–; The movement of jet streams and the wind hodograph 357
–; Theoretical aspects of pressure-pattern flying 21
Scherhag, R.; The significance of three-dimensional weather analysis in forecasting 50
Schonland, B. F. J.; The flight of thunderbolts 359
Schwarz, U. and Neumann, J.; A case of strong turbulence under an inversion 346
Schwarzbach, M.; Das Klima der Vorzeit 331
"Science of Weather" Exhibition ... 177
Scottish Highlands, Ablation in the ... 292

Page

Sea breeze across London 165
–, Variation of wind with height at low levels over the 295
Seamen, Meteorology for 271
Secondary depressions in relation to the thickness pattern, Formation of ... 1
"Sferics" and the lightning discharge ... 277
Shear frequencies in the upper troposphere and lower stratosphere over England 161
Shellard, H. C.; Simultaneous aircraft soundings of temperature and frost point 355
Shoeburyness, Whirlwind at 256
Skelton, P. N.; Centenary of Messrs. Negretti & Zambra 286
Smith, L. P.; Statistisch Onderzock naar de Samenhang Tussen het weer, de Grasproductie, en de Melkaanvoer ... 154
– ; Variations of mean air temperature and hours of sunshine on the weather slope of a hill... 231
Smoke, Radar echoes from 89, 206
Snowstorm during the night of April 25–26, 1950 224
Spring in Kent, Frequency of radiation and wind frosts during 42
Statistisch Onderzock naar de Samenhang Tussen het weer, de Grasproductie, en de Melkaanvoer 154
Stimulation of rain, Artificial 9
Stratosphere over England, Shear frequencies in the upper troposphere and lower 161
Stratus, Method for forecasting the time of clearance of radiation fog or low ... 102
Sun pillar at West Raynham 153
Sunshine every day at Newquay, Long periods with 121
– on the weather slope of a hill, Variations of mean air temperature and hours of... 231
Sutcliffe, R. C.; Variations in the length of the day 353
Sutton, O. G.; Atmospheric turbulence 90
–; U.S. conference on air pollution ... 324
Swinbank, W. C.; Prediction diagram for radiation fog 150
Swithinbank, C.; Oxford University Iceland expedition of 1947 222
Synoptic data, A concise method for recording 11

Temperature and hours of sunshine on the weather slope of a hill, Variations of mean air 231
– – frost point, Simultaneous aircraft soundings of 355
– – humidity lapse rates near the ocean surface 141
– at which radiation fog forms, Notes on 343
– of fog formation, Method of forecasting 213
– over Larkhill, June 1945–December 1947, Frequencies of tropopause ... 27
– rise on clear mornings... ... ...33, 236
–, with application to vertical cross-section diagrams, Variation of geostrophic wind with potential 97

Page
Temperature with season and latitude, Variation of upper air 314
Thickness pattern, Formation of secondary depressions in relation to the ... 1
Thunderbolts, The flight of 359
Thunderstorms 1949, May 14–16, British 28
Thunderstorm Census Organization, Recent work of the 233
– —report of the thunderstorm project 268
– severity in Great Britain, Variations of 233
Tornadoes of May 21, 1950 245
Tropical hurricanes 266
– rainfall from cloud which did not extend to the freezing level 237
Troposphere and lower stratosphere over England, Shear frequencies in the upper 161
Turbulence, Atmospheric 90
– under an inversion, A case of strong 346

United States technical conference on air pollution, May 1950 324
– – Weather Bureau; The thunderstorm —report of the thunderstorm project 268
Universal Decimal Classification 551.5 Meteorology 59, 88
Upavon on November 4, 1949, Unusual fall of rain at 205

Variation of upper air temperature with season and latitude 314
Variations of mean air temperature and hours of sunshine on the weather slope of a hill 231
– in the length of the day 353
– – thunderstorm severity in Britain 233
Vierhout, R. R.; On the formation of drops in cloud and fog 270
Virgo, S. E.; Tropical rainfall from cloud which did not extend to the freezing level 237
Visit of the National Research Council of Canada de-icing team... 330
Vorzeit, Das Klima der 331

Page
Walsrode, Germany, Whirlwind near ... 267
Warren, H. N. 272, 302
Water supply, The geology of 153
Waterspout, Flight through funnel of ... 24
Weather, A chronology of British ... 329
Weather around the year in the British Isles, types and spells of 263
– echoes, Radar 109, 143, 170, 198
– information from British whalers in the Antarctic 299
– lore 302
– systems, The structure of 202
– summaries from Nov. 1949 to Oct. 1950 ... ... monthly
West Raynham, Sun pillar at 153
Wetterkunde, Grundfragen der... ... 301
Whalers in the Antarctic, Weather information from British 299
Whirlwind at Shoeburyness 256
– near Walsrode, Germany 267
Whiten, A. J.; A concise method for recording synoptic data 11
Wilkes, M. V.; Oscillations of the earth's atmosphere 90
Wind and radiation frosts, Frequency of 235
– at Freetown, Diurnal variation of upper 133
– frosts during spring in Kent, Frequency of radiation and 42
– hodograph, The movements of jet streams and the 357
– speed in synoptic reports, Frequency distribution of 22
– with height at low levels over the sea, Variation of 295
Windmill, Orkney 356
Winter gales and Hebridean shipping ... 340

Zealley, P. R.; Obituary notice of Arthur Charles Marsh 272
Zobel, R. F.; The present climatic fluctuation 14

LIST OF ILLUSTRATIONS

Page
Cloud for dry icing ... ... facing 16
Cloud for dry icing }
Cloud-rain after dry icing } ... ... between 16 and 17
Cloud-rain after dry icing ... ... facing 17
Rime at Stonehouse, Gloucestershire, January 26, 1945 ... ... facing 48
Abrekke glacier, Jotunheim, showing recession ... ... }
Plotting a synoptice chart at the Central Forecasting Office, Dunstable, } between 48 and 49
for use on the AIRMET broadcast... ... ... }
Corner of the Communications Room at Central Forecasting Office, Dunstable... facing 49
Radar echo from a column of smoke... ... ... facing 80
Cirrus and cirrostratus above altocumulus ... ... facing 80
Cathode-ray tube used for "Sferic" observations ... ... }
Plotting "Sferic" observations at the Central Forecasting Office, Dunstable } between 80 and 81
Presentations to liner Captains ... ... facing 81
Radar echoes from cold fronts ... ... facing 112
Radar echoes from cold fronts ... ... between 112 and 113
Brewer-Beuttell visibility meter ... ... facing 113
Warm front by radar ... ... facing 144

Page
Warm front by radar ... ... *between* 144 *and* 145
Clear lane cut in altocumulus by an aircraft ... ... *facing* 145
Sun pillar at West Raynham, 1630 G.M.T. January 21, 1950 ... ... *facing* 145
Occlusion by radar ... ... *facing* 174
Occlusion by radar ... ... } *between* 174 *and* 175
A. V. Gotley, Chief Meteorologist and Officer in Charge, Heard Island } *between* 174 *and* 175
General view of camp at Heard Island ... ... *facing* 175
Central dome at Heard Island ... ... *facing* 175
Unusual radar weather echoes ... ... *facing* 200
Unusual radar weather echoes ... ... *between* 200 *and* 201
Cumulus cloud from a fire ... ... *facing* 201
Telegraph wires sagging under the weight of snow at South Farnborough, 0700 G.M.T., April 26, 1950 ... ... *facing* 228
Branch severed from a tree at Aldershot, 1130 G.M.T., April 26, 1950 ... ... *facing* 228
Brushing snow off a French Bristol Freighter at Blackbushe Civil Airport at about 0900 G.M.T., April 26, 1950 ... ... } *between* 228 *and* 229
Tudor House, Yately, Camberley, Surrey, around 0700 G.M.T., April 26, 1950 ... ... } *between* 228 *and* 229
Snow on the north side of a small tree, at Tudor House, Yateley, around 0700 G.M.T., April 26, 1950 ... ... } *between* 228 *and* 229
Meteorological Officers of the Netherlands' O.W.S. *Cumulus* at Station JIG, April 1950 ... ... } *between* 228 *and* 229
Netherlands' O.W.S. *Cumulus* at Station JIG, April 1950 ... ... *facing* 229
The main tornado approaching Halton R.A.F. Station ... ... *facing* 252
Torn and broken tree at Sutton, Ely... ... ... *facing* 253
Up-stream face of the main Caban Dam, Rhayader Waterworks... ... ... *facing* 260
Scenes of havoc, Linslade } ... ... *between* 260 *and* 261
Overturned bus at Sutton, Ely } ... ... *between* 260 *and* 261
Careg Ddu viaduct, showing effects of drought ... ... *facing* 261
Hailstones at North Crawley, near Newport Pagnell, Bucks. ... ... *facing* 268
Three-legged race at the Harrow Meteorological Office Sports meeting, July 26, 1950 ... ... *facing* 269
Lightning photograph at Springsure, Queensland ... ... *facing* 284
Photograph of laboratory spark (8 cm. long) taken with a rotating camera ... *facing* 285
Henry Negretti... ... ... *facing* 300
Joseph Warren Zambra ... ... *facing* 300
Slotted sunshine-recorder ... ... *facing* 300
French O.W.S. *Laplace* ... ... *facing* 301
Aerial view of Eskdalemuir Observatory ... ... *facing* 344
Interior of east absolute hut, Eskdalemuir Observatory ... ... *facing* 345
Artist's impression of windmill for electricity generation on Costa Hill, Orkney *facing* 356
Trophies at present held by the Meteorological Office ... ... *facing* 357

ERRATA

PAGE 54, REFERENCES:

No. 4, *for* "MOLLWO, H. VON" *read* "MOLLWO, H".
No. 5, *for* "REINEKE, INGRID VON" *read* "REINEKE, INGRID".
for "*Met. Z., Braunschweig*" *read* "*Z. Met., Potsdam*".
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See also pages 49, 91 and 333.

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FORMATION OF SECONDARY DEPRESSIONS IN RELATION TO THE THICKNESS PATTERN

By J. S. SAWYER, M.A.

The thickness chart has recently been brought into increasing use for the purpose of forecasting the development of the synoptic weather situation. Charts of the thickness of the atmospheric layer between pressure levels of 1000 and 500 mb. are used at the Central Forecasting Office, Dunstable, and the properties and significance of such charts have been described by R. C. Sutcliffe[1]*, who has also shown[2] that a theoretical relationship can be established between the curvature and shear of the "thermal-wind"† field and the cyclonic or anticyclonic development which must accompany it. The present note outlines the results of investigations which have recently been conducted in the Forecasting Research Division to determine the characteristic features of the thickness chart which accompany the formation of secondary depressions. So far the study has been confined to secondaries which form either at the point of occlusion of the primary depression or as waves on the warm front; it is hoped to publish a more complete account of the work when it has been extended to other synoptic developments.

Characteristic thickness pattern associated with secondaries at the point of occlusion.—It has been found that secondaries forming at the point of occlusion can be divided conveniently into two types according as the occlusion on which they form is of the cold or warm type. Characteristic patterns associated with secondaries on warm and cold occlusions are illustrated in Figs. 1 and 2.

The features of the isobaric and thickness pattern which are found to provide significant criteria for such development are as follows. For secondary formation at the point of occlusion of a warm occlusion there must be:—

(*a*) a slow-moving primary depression;

(*b*) a notably strong thermal gradient of warm-front type ahead of the primary (somewhere to the east) with the maximum gradient displaced some distance from the centre of the primary. The thermal wind (1000–500 mb.) is usually 40–80 kt.

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*The index numbers refer to the list of references on p. 5.

†The thermal wind is obtained by application of the geostrophic wind relation to the thickness chart.

For secondary formation at the point of occlusion of a cold occlusion there must be:—

(*a*) a strong thermal gradient displaced several hundred miles from the centre of the primary—the thermal gradient over the centre of the primary is relatively weak and the primary is usually slow moving.

(*b*) a marked fanning out of the thickness lines ahead of the point of occlusion from the region of strong thermal gradient behind it (*i.e.* usually to the west).

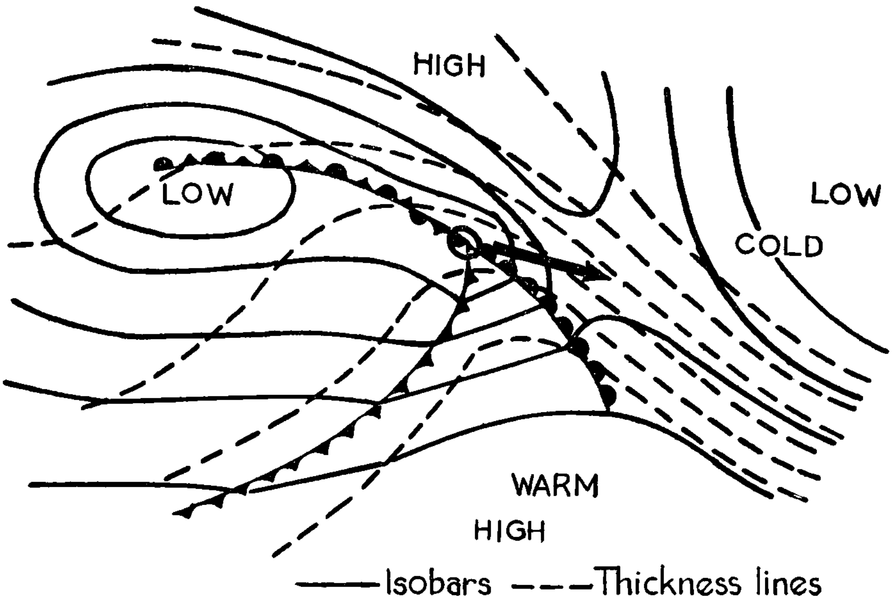

FIG. I—CHARACTERISTIC ISOBARIC AND THICKNESS PATTERN LEADING TO THE FORMATION OF A WARM-OCCLUSION SECONDARY

The fanning out of the thickness lines is conveniently described as " difluence " of the thermal winds, and the converse running together of the thickness lines as " confluence ". In conformity with the rules above, secondaries on warm occlusions form just to the right of a " confluence " in the thermal pattern, and secondaries on cold occlusions form to the left of a " difluence ". These are both areas which R. C. Sutcliffe has shown theoretically to be associated with cyclonic development.

TABLE I—SUMMARY OF RESULTS OF TEST OF CRITERIA FOR THE FORMATION OF SECONDARY DEPRESSIONS AT THE POINT OF OCCLUSION

Period October 1947 – September 1948
Each occlusion is counted once only in the table

	No secondary expected	Cold occlusion secondary expected	Warm occlusion secondary expected
No secondary formed	137	14	9
Secondary formed	14	40	23

Total successes = 200 Total failures = 37

A test of the above criteria has been made on the basis of a series of a year's charts which carried the surface isobars and thickness pattern. In order to simulate forecasting practice an assessment was made on each chart in respect of each occlusion present as to whether a secondary should, or should not, subsequently form. The results, which are given in Table I, suggest that the rules should provide a useful forecasting tool. The criteria can be regarded as both necessary and sufficient for secondary formation.

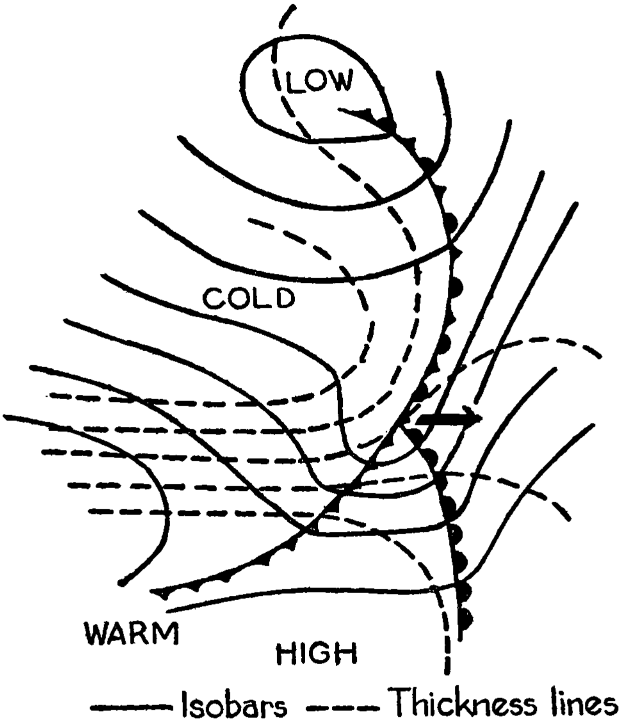

FIG. 2—CHARACTERISTIC ISOBARIC AND THICKNESS PATTERN ACCOMPANYING THE FORMATION OF A SECONDARY ON A COLD OCCLUSION

Characteristic thickness pattern associated with warm-front waves.—The thickness pattern associated with the rather unusual formation of a wave on the warm front of a primary depression has also been investigated. It has been found that the thickness pattern is the same as that associated with warm-occlusion secondaries, and Fig. 3 shows the relation of the fronts to the thickness pattern. Out of 19 warm-front waves noted during the period September 1946–September 1948 only one failed to show these characteristic features. Certain slow-moving secondaries which form on cold fronts have a similar thermal structure to that of the cold-occlusion secondaries, but the usual fast-moving cold-front wave has not yet been studied.

Other characteristics of warm-occlusion secondaries and warm-front waves.—Once formed the behaviour of warm-occlusion secondaries and warm-front waves is very similar. They move quickly away from the primary at a speed usually between 30 and 50 kt. For this reason both types are sometimes referred to as " break-away " depressions. The direction of motion closely follows the thickness line over the centre; but, because of the distortion caused by the secondary itself, it tends to be inclined slightly towards the cold side of the strong thermal belt which existed before the secondary appeared; the average inclination is about 10 degrees for warm-front waves and 30 degrees for warm-occlusion secondaries.

The central pressure of both types of secondary tends to rise, although they may deepen later after they have crossed the ridge ahead of them. However, these secondaries are often responsible for a noteworthy penetration of rain into the high-pressure area.

Characteristics of secondaries on cold occlusions.—The behaviour of secondaries on cold occlusions is less regular than that of those on warm occlusions, and it seems to be more dependent on the details of the thickness pattern around them. If the difluence of the thickness lines is broadly symmetrical, as indicated in Fig. 2, a rather slow motion is usual in the general direction of the strong thermal winds. A speed of 10–20 kt. can be expected. However, if the thermal gradient is stronger in the left-hand or right-hand branch of the difluence, corresponding motion towards the left or right is probable, and the speed is somewhat greater than in the symmetrical case. Although these secondaries often go through a short-lived phase of rapid deepening very few become major features of the synoptic chart.

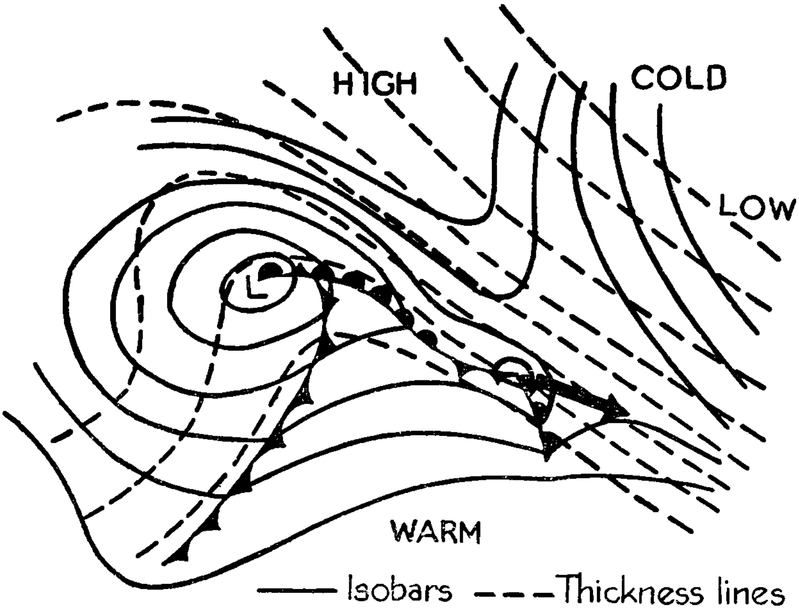

FIG. 3—CHARACTERISTIC ISOBARIC AND THICKNESS PATTERN ACCOMPANYING THE FORMATION OF A WARM-FRONT WAVE

There is an important association between secondaries on cold occlusions and the "jet stream", the narrow belt of exceptionally strong wind in the upper troposphere which has been studied by E. Palmén[3] (see also Meteorological Office Discussion[4] on October 25, 1948). A jet stream will usually be found above the strong thermal belt behind the point of occlusion at which a secondary forms. The secondary forms beneath the left exit from the jet, and the changes in the flow which accompany the development of the secondary result in the extension of the jet in the direction of the stream.

Application to forecasting practice.—The application of the above facts to forecasting practice depends on the forecaster's ability to decide in advance that the characteristic pattern will occur. This is usually possible. Moreover, there is usually a lag of up to 24 hours between the first appearance of the characteristic pattern and the formation of a secondary; the lag is greater for warm-type secondaries.

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ARTIFICIAL NUCLEATION OF CLOUDS

By RONALD FRITH, Ph.D.

Since the reports of the artificial production of precipitation by Langmuir in America[1]* and Kraus and Squires in Australia[2] further experiments on similar lines have been made in those and several other countries. Moreover, the physics of the problem has been extensively discussed by Bergeron[3] and others. The purpose of the present note is to recapitulate some of the main issues which have emerged and to report briefly on a few experiments carried out by the Meteorological Research Flight in the United Kingdom during the past two years.

It is generally accepted that if a cooling agent, for example solid carbon dioxide (dry ice), be scattered into a cloud of supercooled water drops, ice crystals will be formed. Owing to the difference of vapour pressure between ice and supercooled water at the same temperature these ice crystals will grow—and they will grow the more rapidly the greater this difference of vapour pressure and the greater the water content of the cloud. Thus, whenever there are ice crystals present, the amount of supercooled water will decrease steadily and the ice crystals will grow. Eventually the cloud may consist entirely of ice crystals; or it may revert to the supercooled-water state; or it may clear completely—depending on the number of ice crystals present:—

(*a*) With very large numbers of crystals, even when all the water has been sublimated on to the crystals, they are still small and an ice-crystal cloud is left.

(*b*) With very few crystals, each crystal grows rapidly and precipitates out, leaving behind a thinner, supercooled-water cloud.

(*c*) With moderate numbers of crystals, all the water is sublimated on to the crystals, but by that time they are large enough to have a significant falling speed. They therefore precipitate out and clear air is left. The falling crystals may either reach the ground as rain or snow or, more generally, they will evaporate in the drier air below the cloud.

Some experiments of Findeisen, recently repeated at Oxford, suggest that a growing ice crystal will itself generate new, and separate, ice crystals—conveniently thought of as " splinters ". It is also possible that real splinters may arise through mechanical breakage; and other ways have been suggested in which the presence of one ice crystal may give rise to others—and these, in turn, to others.

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*The index numbers refer to the list of references on p. 9.

The existence of any such chain-reaction process may account for the apparent relative unimportance of the original rate of seeding, which has been noticed both by us and in experiments in other countries.

Applications of artificial nucleation.—The possible applications of this new technique may be summarised under three heads:—

(*a*) To produce rain where none would otherwise have occurred.

(*b*) To control rain—*e.g.* to cause it to occur earlier, or in other places, or to prevent the occurrence of torrential rain, hail and thunderstorms.

(*c*) To clear cloud.

These applications will be discussed in turn and we will describe our own experiments under each heading.

(*a*) *To produce rain.*—Seeding a supercooled cloud will always produce precipitation, unless the seeding is on such a scale that very large numbers of ice crystals are formed. It is not at all certain what rate of seeding would be required for this latter effect—it certainly depends upon the temperature and the nature of the cloud, and also upon the size of the ice pellets used. We have always used pellets about the size of peas, and generally rates of ten pounds or less per mile run. Except in the case of thin, very cold clouds—where a rate of 2–3 lb./mi. is apparently sufficient to convert the cloud to an ice-crystal cloud (see our experiment of August 16, 1949)—it seems that rates of much greater than 10 lb./mi. would generally be required. Provided that we seed at lower rates than this maximum, precipitation will always result. Normally the precipitation will continue until there is no cloud left, or until all the ice crystals have fallen out. In either case the amount of precipitation cannot be appreciably greater than the amount of water originally in suspense in the cloud. For all practical purposes this amount is trivial. To obtain any significant amount of rain it is necessary to have conditions in which the cloud is being constantly renewed, and in which, also, there is a constant supply of ice crystals.

These conditions may arise in two ways:—

(i) Where there is unlimited cloud—as, for example, when orographic cloud is being formed in air flowing over some obstruction. It is not known whether any chain-reaction process would be sufficient, after an initial seeding, to maintain precipitation indefinitely, or whether continuous seeding would be necessary. Probably the latter. If so it might be that a silver-iodide smoke, generated at ground level, might be an effective agent, as suggested by Langmuir and others[1]. Any such cloud would, of course, have to extend to levels where the temperature is appreciably below freezing. Experience suggests that whenever orographic cloud of such a nature exists in this country it is always raining, or snowing, already.

(ii) Where a direct consequence of the seeding is the production of a self-generating storm. At least two experiments have been reported[1 2] in which seeding with dry ice was followed by the development of a much larger cloud from which rain fell in appreciable quantities for some hours. On both occasions, however, conditions were very suitable for the development of natural storms, and it seems probable that the balance of stability was just tipped, either by the release of latent heat as the supercooled water turned into ice (Bannon[4]) or by the increased buoyancy due to the release of precipitation from the cloud, or both. A self-generating storm has never been produced in this country.

The necessary conditions are very critical, and it is probably true to say that the cloud must, in fact, be on the point of precipitating anyway. So that it is unlikely that rain, which would not have fallen otherwise, can be produced in this way.

(*b*) *To control rain.*—If it were possible to tell, at a sufficiently early stage, which cloud was going to develop into a thundercloud, seeding this cloud at the appropriate moment might possibly prevent the occurrence of a thunderstorm, replacing it, perhaps, by a longer period of less intense rain. In fact, however, thunderstorms develop very quickly, and it is extremely difficult for an aircraft to be in the vicinity of the right cloud at the right time.

Moreover, when studying the effect of a seeding, one can never know what would have happened had the seeding not taken place. In countries where thunderstorms are common it should be possible to carry out a rigorous investigation in this way; whenever a suitable cloud is found a decision whether to seed it or not is made by spinning a coin. Whether seeding takes place or not, the developments of the cloud are followed in exactly the same way. Only by some such expedient can the effects of seeding incipient shower clouds be studied.

Widespread and continuous seeding from the ground, by silver-iodide smoke or other means, would probably alter the whole character of convection weather and might well prevent thunderstorms altogether.

We have not made many attempts to control the development of cumulus clouds—mainly because of the impossibility, as we have pointed out, of interpreting the results. The two experiments which we have carried out both resulted in the clouds precipitating for a while and then dispersing from the base upwards.

November 3, 1947.—There were several large cumulus clouds with tops to about 12,000 ft. (temperature about 6°F.) and one or two had anvil tops. We chose one which was smaller than the rest and had no anvil top. In two runs through the cloud we dropped about 120 lb. of dry ice. After 30 min. the cloud had grown from about 11,000 ft. to about 14,000 ft. and an anvil had formed. However, practically every other cloud in the area had also grown and some had formed anvils. But from being one of the smallest ours was now as large as any save one. Slanting views showed that rain was falling. After 40 min. there was practically nothing left of our cloud except the anvil, from which some precipitation was still falling. There were no radar observations of this experiment.

August 30, 1949.—Cumulus clouds, without anvils, with tops to 15,000 ft. (temperature about 16°F.) were giving radar echoes. All these clouds were found to contain ice crystals. A somewhat smaller cloud, top 14,000 ft., which was not giving an echo was selected. This cloud was found not to contain ice crystals. In three runs over the cloud 50 lb. of dry ice were dropped. At first there was a slight lowering of the cloud top but after 10 min. there were signs that the top was becoming ragged and it had risen to its original height. At the same time a small echo was received by the ground radar station. Ice crystals were found in the cloud and rain was falling from it. After 45 min. the echo had gone, the rain had stopped, and there were no longer ice crystals in the cloud.

(*c*) *To clear cloud.*—It is necessary to distinguish between precipitating and non-precipitating supercooled cloud. It is our experience that if a supercooled cloud is precipitating there always exist within it large numbers of ice crystals. From what we have said earlier about the relative unimportance of the rate of seeding (perhaps because there is some process whereby the presence of one ice crystal produces large numbers of others) it seems probable that seeding an already precipitating cloud will have little effect—unless it is possible to introduce so many ice crystals at once that the cloud becomes, for the time being, an ice-crystal cloud. If it does so the precipitation should cease.

The cessation is almost bound to be only temporary since the fact that the cloud continues to exist, in spite of the precipitation that is occurring, indicates that vertical ascent of air is continuously renewing the cloud.

We have ourselves seeded precipitating cloud on two occasions:—

June 21, 1948.—Dry ice was dropped into a sheet of cloud whose top was at about 10,000 ft. and temperature about 22°F. The cloud covered a wide area, but radar echoes were being received only locally. The part of the cloud which we seeded was giving an echo. After seeding, the ground radar station reported that there did appear to be a clear lane through the echo where we had seeded—but the whole cloud sheet was breaking up and identification was difficult.

September 21, 1949.—Convergence into a trough was giving widespread cloud and local areas of rain. The cloud base was at about 6,000 ft. but very variable. The top of the first layer was at about 16,000 ft. with another layer, base at about 18,000 ft., above—but these two layers appeared to join up in places. We seeded from 16,000 ft. over a bright-band type of echo (temperature about 5°F.). Although the cloud we were ourselves in at the time of seeding appeared to consist entirely of ice crystals, the sun, when it was visible, was surrounded by a corona—indicating the presence above us of water drops. We seeded for about 10 miles at the rate of 8 lb./mi. No effects were observed either by radar or visually.

In the case of non-precipitating supercooled clouds, seeding will result in the production of precipitation and will often leave a cleared lane in the cloud.

It has been suggested that a path could be cleared in this way through which an aircraft could ascend or descend in icing clouds. However, in our experience these non-precipitating supercooled clouds are always shallow and never give rise to serious icing.

It is possible, of course, that supercooled fogs or low stratus clouds might be cleared by seeding—but these are quite rare phenomena in this country.

In spite of the fact that these experiments may have little "practical" value, they are well worth doing. For we believe that a study of the way in which a clearance, once formed, spreads through the cloud, and how it eventually fills in again (if it does) might give useful information on atmospheric processes—especially turbulence.

Unfortunately continuous sheets of non-precipitating supercooled clouds are suprisingly rare. During the past two years we have been able to experiment on only two—and in neither case were we able to make any detailed study of the effects of the seeding.

August 16, 1949.—There was a sheet of altocumulus cloud at 25,000 ft., about 500 ft. deep, temperature about −14°F. It was a pure-water cloud where we flew through, but virga was visible in one place in the distance indicating the existence there of ice crystals. We flew above this cloud and seeded it at the rate of about 2 lb./mi. for 25 mi. Looking back, the effect of the seeding was quick and marked. Cumuliform heads rapidly developed along the line of seeding—each head being at first quite separate from the next, although seeding had been almost continuous. The line of cumulus showed very white against the general dark background of the rest of the cloud. The cumulus heads dispersed and the ice-crystal lane spread sideways for a while and then seemed to disappear. It did not seem that any clear lane was opened up in the cloud. Flying below the cloud later a magnificent halo complex was observed. Although it is certain that this complex arose from the cloud at 25,000 ft.—and not from a fairly extensive layer of cirrus at a much higher level—we cannot be sure that it was from the part of the cloud which we had seeded.

September 1, 1949.—A sheet of non-precipitating altocumulus cloud with top at about 15,000 ft. (temperature about 10°F.) and about 4,000 ft. deep was seeded at the rate of about 6 lb./mi. Unfortunately the whole cloud sheet was breaking up rapidly, and it was quite impossible to observe whether the seeding had had any effect or not. No radar observations were available.

The author has had described to him, and he has himself seen, on days of broken altocumulus cloud, instances of aircraft leaving contrails when in clear air, but, when passing through a sheet of cloud, leaving a clear lane. It is believed that this also is an example of the artificial nucleation of supercooled cloud. For if the contrail consists of ice crystals then, inside the supercooled cloud, these ice crystals will grow and precipitate out, leaving a clear lane through the cloud.

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ARTIFICIAL STIMULATION OF RAIN

In July 1949, Imperial Chemical Industries Ltd. decided that, unless substantial rain soon fell in the catchment area near Teesdale, production by certain factories on Teeside would be severely restricted owing to lack of water. I.C.I. Ltd. therefore were prepared to attempt artificial stimulation of rain by " seeding " suitable clouds with " Drikold ", one of their products, more commonly known as solid CO_2 or " dry ice ". With the authority of the Air Ministry a Wellington aircraft from Middleton St. George was adapted for the experiments, and arrangements were made for special forecasts to be issued by the Central Forecasting Office.

The main conditions regarded as suitable for the experiments were:—

(*a*) Clouds were to be cumulus in the developing stage, of about 10,000 ft. in vertical extent.

(*b*) Clouds must extend at least 3,000 ft. above the freezing level.

(*c*) Sufficient free water must be present in the cloud to liberate enough heat on freezing to promote further convection.

The table below gives the chief data relating to the three attempts that were made:—

TABLE I

Date	Time of seeding	Top of cumulus cloud	Air temperature at cloud top	Height of freezing level	Amount of " dry ice "
	B.S.T.	ft.	°C.	ft.	lb.
August 3	1723	10,000	−4	6,000	200
August 8	1703	10,000	−3	6,000	300
August 11	1350	8,000	0	8,000	300

On the first experiment, near Appleby, no upward growth of the cloud was observed, but a slight rain shower commenced within ten minutes of the seeding. No precipitation had previously been seen in the district that day, but, half an hour after the seeding, a ground observer near Richmond, Yorkshire, noted a moderate shower, with pronounced trailing virga, from an isolated cumulus cloud to the north. This may have been the cloud which was seeded.

The second attempt made to the east of Penrith was more successful (see photographs facing pp. 16–17). By 1711 B.S.T. the cloud top had risen about 500 ft. The Wellington descended rapidly; at 1723 cloud base had lowered from 3,000 ft. to 2,300 ft., and a heavy shower was falling. At 1730 the shower was of moderate intensity. No other precipitation was observed in the district.

Four minutes after seeding, on the third attempt, the cloud top had risen 200–300 ft. While flying at 4,000 ft. through the cloud six minutes later, very slight rain was experienced. At 1410, very slight rain was falling from the cloud (cloud base 2,000 ft.). This third attempt might have been more successful had it been carried out a few hours earlier, when clouds were in the developing stage and many of the tops were over 10,000 ft.

Soon after August 11 the water crisis on Teeside ended owing to the fall of natural rain, and the experiments were discontinued.

There are 40 to 50 stations which measure rainfall within about 30 miles of the location of these experiments. Returns from these stations were specially called for, and the daily amounts and the observers' comments of the time of the rain have been examined, together with the autographic records from Forest-in-Teesdale, Darlington and Durham with the following results:—

August 3.—No rain was recorded over a wide area, except a " trace " at one station two hours before seeding and a shower at another station about 25 miles away and 37 minutes after seeding.

August 8.—One slight shower may have been connected with the seeding, as recorded at Forest-in-Teesdale some 7 minutes after seeding. During the night after the seeding (which occurred at 1703) rain fell at many places within 30 miles.

August 11.—Most stations recorded no rain at all for this day. At Forest-in-Teesdale there was no rain apart from 0·01 in. about four hours before the seeding occurred.

The observer at Middleton-in-Teesdale (not far from Forest-in-Teesdale) stated " there was no obvious effect on the weather by artificial action on the three days mentioned above."

A CONCISE METHOD FOR RECORDING SYNOPTIC DATA

By A. J. WHITEN

In the course of a piece of work recently undertaken, it has become necessary to devise a code for recording synoptic events day by day, which, besides occupying a minimum of space, lends itself readily to sorting and classification for statistical purposes. As this code may possibly be of use to others with a similar problem, a brief account follows.

For purposes of analysis, the United Kingdom is divided into seven areas, roughly equal in extent. This is done by drawing a line from Spurn Head to Birkenhead, another from Thames to Severn, and one through Oxford and Southampton. The Scottish border and a line from Dundee to Oban separate north England, and the Highlands and Lowlands of Scotland. The remaining four districts are east, west, south-east and south-west. It is recognised that this division of the country is useless for forecasting purposes, but as hydrometeors cross the country with only limited regard for orographic features, approximate equality of the districts is the main consideration.

A code record is compiled daily for each district. Curvature of isobars is first represented by the use of large capital letters:—

A represents anticyclonic circulation;
B shows that the site lies in a col;
C represents cyclonic circulation.

This letter is followed by two suffixes, locating the nearest, or most significant, centres of high and low pressure, the direction being shown in compass points, the distance in hundreds of miles. High pressure is indicated by the upper suffix, low pressure by the lower one.

Movements of fronts are shown by the use of large figures, as follows:—

1 = warm front;
2 = cold front;
3 = warm occlusion;
4 = cold occlusion;
5 = stagnant front.

Each frontal figure is followed by two suffixes. After numbers 1 to 4, the upper suffix shows direction of movement by small capital letters, and time of passage over the centre of the district by figures, showing G.M.T. on the 24-hr. clock. The lower suffix indicates the alignment of the front at a standard hour (the same as that represented by the suffixes after the large capital letters). This is done by stating the direction of a normal from the centre of the district to the nearest point on the front at that hour. A figure is added to indicate the intensity of the front. In the case of stagnant fronts the procedure is slightly different as time of passage does not arise; in this case the upper suffix shows whether the district is situated in the warm or cold air mass with relation to the front.

Up to the present, the figure indicating the intensity of fronts has been the apparent difference in temperature between the adjacent air masses. This, however, is very difficult to ascertain with confidence from the data available to the investigator, which is limited to the *Daily Weather Reports.* It would probably be more satisfactory to indicate the change of pressure in millibars. The use of plus and minus signs should be unnecessary, as the character of the front should indicate whether the pressure is rising or falling. The alternative possibility, of recording change of wind force and direction, would introduce a rather undesirable complication into what is, in spite of its somewhat fearsome appearance at first glance, really a very simple code to employ.

The following example, and its " translation ", will show how much space can be saved by its employment, quite apart from the fact that each detail is readily available for statistical classification.

MONDAY	TUESDAY	WEDNESDAY
$\mathrm{C}\,\substack{\mathrm{SW/12}\\ \mathrm{NW/5}}\ 1\,\substack{\mathrm{E/17}\\ \mathrm{E/3}}\ 2\,\substack{\mathrm{E/23}\\ \mathrm{W/5}}$	$\mathrm{C}\,\substack{\mathrm{SW/11}\\ \mathrm{N'E./4.}}\ 4\,\substack{\mathrm{SE./8}\\ \mathrm{E./2}}$	$\mathrm{A}\,\substack{\mathrm{SSW/3}\\ \mathrm{NE./9}}\ 5\,\frac{\mathrm{W.}}{\mathrm{N/2}}$

The above would read as follows:—

" On Monday (at the standard hour) the district was situated in a cyclonic circulation. Effective high pressure was 1,200 miles to the south-west; low pressure, 500 miles to the north-west. At 1700 G.M.T. a warm front went through, moving eastwards. At the standard hour, the alignment of this front was from north to south. The approximate temperature difference across the front was 3°F. At 2300 G.M.T. a cold front went through, moving towards the east. Alignment north to south, temperature difference about 5°F.

" On Tuesday circulation was still cyclonic, high pressure 1,100 miles south-west, low pressure 400 miles north by east . At 0800 G.M.T. a cold occlusion went through to south-east, alignment north to south, temperature difference 2°F. approximately.

" On Wednesday the circulation was anticyclonic; high pressure south-south-west, 300 miles; low pressure, north-east, 900 miles. The district was under the influence of a stagnant front, situated to the north, aligned east to west, temperature difference approximately 2°F. The district was in the warm air mass in relation to the front."

It will be unnecessary to point out how much more can be deduced from such a record than is actually noted.

In the preparation of this code valuable advice, as to what was needed and what was impossible, was given by Cdr. G. L. Hogben.

RELATIONSHIP BETWEEN THE AVERAGE MONTHLY RAINFALL AND THE AVERAGE NUMBER OF DAYS PER MONTH WITH 0·4 in. OR MORE OF RAIN

By E. V. NEWNHAM, B.Sc.

The average number of days per month with 0·40 in. or more rain, referred to in this note as N, is sometimes included among meteorological statistics, *e.g.* in Admiralty " Pilots ", where it is taken to represent the number of days of " considerable rainfall ". It often happens that daily totals of rainfall, from which N could be obtained, are not published, and N is estimated from the mean monthly rainfall, R. The object of this investigation is to obtain rough relationships between N and R for temperate and tropical latitudes.

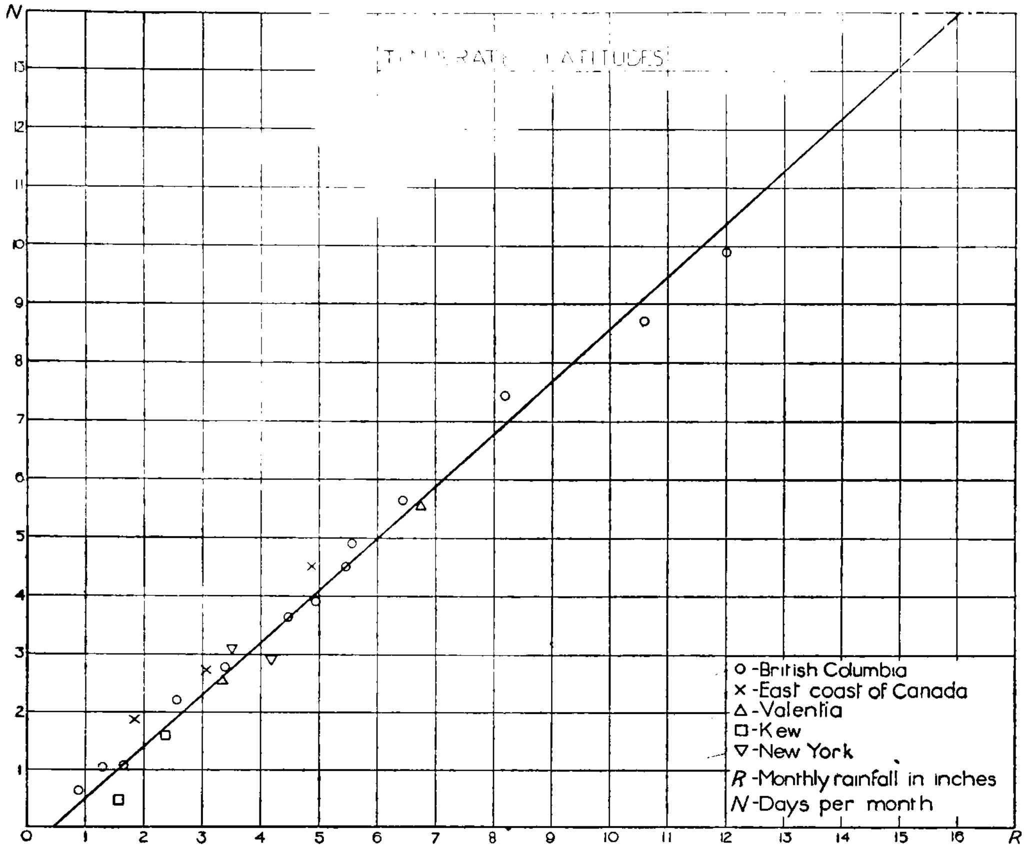

FIG. I—THE RELATIONSHIP FOR TEMPERATE LATITUDES

The relationship for temperate latitudes is shown in Fig. 1, where N is plotted against R. For Kew, Valentia and New York the means of R and N for the months of greatest and least rainfall are shown, but for the coasts of British Columbia and eastern Canada it was found more convenient to group several stations of roughly equal average rainfall together and obtain monthly means

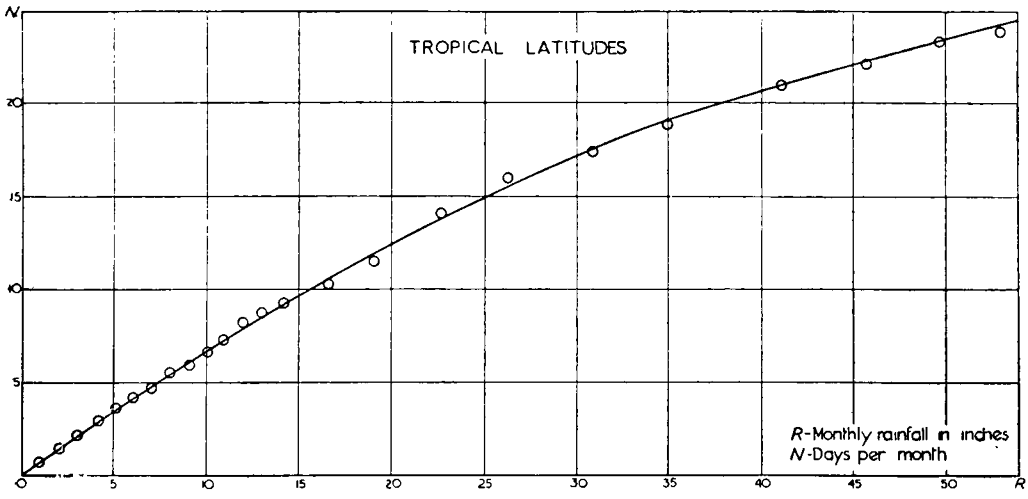

FIG. 2—THE RELATIONSHIP FOR TROPICAL REGIONS

for a relatively short period (5 yr.). It appears from the graph that

$$N = 0{\cdot}9\,R - 0{\cdot}4 \text{ approximately}$$

and that N obtained from this formula should generally be within a day or two per month of the correct value.

The relationship for tropical regions is shown in Fig. 2. Here each point is obtained by grouping together from among the monthly means those having about the same average rainfall, and averaging N and R for the group. The number of monthly means in a group averaged about 15, and the length of record used averaged about 22 yr., consequently each plotted point is on an average the mean of more than 300 pairs of observations of N and R. It will be seen that up to about $R = 10$ in. the relationship is very nearly $N = \frac{2}{3}R$, but that for higher values of R the slope of the graph steadily decreases. Since Fig. 2 does not show the amount of variation of N for a given R, and therefore does not show the amount of error to be expected when estimating N from R by means of the graph, the following table has been added:—

PERCENTAGE FREQUENCY OF ERRORS OF ESTIMATE OF N FROM THE GRAPH IN FIG. 2

(based on 252 monthly means)

Limits of R	Error of estimate (days per month) 0	1	2	3	4
			per cent.		
< 10 in.	79	21	0	0	0
10–20 in.	50	35	7	8.	0
20–30 in.	20	23	46	11	0
30–40 in.	13	40	27	13	7
40–50 in.	26	53	21	0	0
50–55 in.	50	50	0	0	0

The stations used were Batavia, Fiji, Mauritius, Tulagi (Solomon Is.), Samoa, Fanning Island, Christmas Island, Colombo, and 36 stations on the coasts of India and Burma, which last provided all the monthly means with R more than 18 in.

METEOROLOGICAL OFFICE DISCUSSION

November 7, 1949. The present climatic fluctuation. By Hans W:son Ahlmann (*Geogr. J., London,* **112**, 1949, p. 165). Opener—Mr. R. F. Zobel.

Changes of climate of varying orders of magnitude are known to have occurred many times in the past, as, for example, in the formation and disappearance of ice ages.

A deterioration of climate occurred in the higher northern latitudes about 1200–1300 A.D. Over the last 100–150 years, however, there are many indications that there has been a noteworthy amelioration. This amelioration is referred to as the present climatic fluctuation.

Climatological evidence of the present fluctuation.—The longest series of temperature records comes from Holland. It dates from the beginning of the eighteenth century. By using 30-year overlapping means, the records show that the winter temperatures decreased from the first half of the eighteenth century to a minimum in the beginning of the nineteenth century. Since then an increase has prevailed to this day. Changes at other seasons are small.

Similar analysis of temperature records for places in England, Sweden, Norway, Denmark, Finland and the U.S.S.R. shows the same general trend, but the most outstanding increase of temperature is recorded in winter at Spitsbergen, where mean winter temperatures, computed in 10-year overlapping means, rose by more than 7°C. between the periods 1908–17 and 1928–37.

Lysgaard has given a summary of the thermometric evidence of the recent fluctuation by stating that both winter and summer temperatures have shown an appreciable increase over great parts of the earth, especially the temperate and arctic zones, whilst over the tropical and subtropical zones a decrease has taken place. This view is also taken by Ångstrom.

The immediate cause of the improvement of climate in high northern latitudes is undoubtedly increased atmospheric circulation, resulting in increased advection from low to high latitudes. Since the area of the tropics is large compared with that of high latitudes, increased circulation would be expected to produce a small fall of temperature in low latitudes and a comparatively large rise in high latitudes, which is broadly the effect observed during the recent climatic fluctuation.

Increased circulation also affects the distribution of rainfall and changes in this respect have also been observed. Though rather variable from place to place the precipitation over Norway as a whole has increased by about 10 per cent. in the last 100 years, whilst there has been a similar trend in Sweden. Once again Lysgaard has summarised the changes in global distribution by stating that from the period 1881–1910 to the period 1911–40 precipitation has increased throughout the arctic and much of the temperate zone, whereas there has been a decrease in tropical and subtropical regions with the exception of the monsoon regions of south-east Asia. This statement is supported by the fact that there has been a considerable lowering of the level of lakes in east Africa, whilst the Sahara is tending to spread slowly southwards.

It is not yet possible to say with certainty that the climatic fluctuation is world-wide, but the larger the number of places examined becomes, the greater becomes the evidence. The main gap in the evidence occurs in the southern hemisphere, notably in the Antarctic. If it can be shown that this area is affected also, then it can be said that probably all regions have been affected, in which case it seems most likely that the fundamental cause of the fluctuation of climate must be looked for in changes of solar radiation, possibly connected with sunspots.

Much work remains to be done before it will be possible to be certain of the causes of the fluctuation, but this is the first fluctuation in the endless series of past and future climatic variations in the history of the earth which can be measured, investigated and possibly explained. It is, therefore, important to ascertain in what other ways the climatic change has been manifested and has thus provided confirmatory evidence.

Glaciological evidence.—Thorarinsson has made an extensive study of glacier variations and comes to the conclusion that " the marginal variations of the glaciers in recent centuries have in all probability been more or less concurrent all over the world ", whilst Matthes says " glaciers in nearly al parts of the world receded irregularly during the last 60 years, but especially rapidly during the 1931–40 decade ".

The reduction in glacier volume in the North Atlantic area began about 200 years ago, at which time the local glaciers reached their maximum extent in historical times, perhaps even in post-glacial times. All the glaciers in recession are losing more material by ablation than they receive by accumulation of snowfall. This means that the rising temperature has been sufficient to overcome the tendency to create glaciers through the increased precipitation.

A plate will be published in the next number of this Magazine giving photographs of the Åbrekke glacier near Jotunheim in south-west Norway, taken in 1869, 1933 and 1946, which shows a very marked recession.

Oceanographical evidence.—Investigations in various districts of the northernmost Atlantic show that there has been an increase of sea temperature and also of salinity. This warming has resulted in a reduction of the thickness of the ice in the Polar Sea. Pack-ice is also less extensive in general. In fact, the shipping season for Spitsbergen coalfields is now about seven months as against three months at the beginning of the century.

Biological evidence.—The increased warmth of northern waters has caused fish, notably the common cod, to migrate northwards. At the beginning of the century cod was rare in Greenland waters. Now it is abundant and has become practically the staple diet of the Greenlanders.

Birds and insects have shown similar tendencies as illustrated by the fact that species common in Iceland are being slowly replaced by more southerly species.

Prospects for agriculture have become much improved in Sweden and Finland due to the increased growing period which amounts to an additional 2–3 weeks per year. This has also affected the northern forests in such districts as Scandinavia, Finland and Alaska where the timber-line is spreading northwards, whilst the trees show increased growth and a greater fertility.

Eustatic evidence.—The part played in the rise and fall of sea level by repeated release and absorption of water in ice-caps is known as glacial eustasy.

It might be expected that the present melting of the glaciers would raise the level of the oceans. This is in fact the case, though measurements in different parts of the world indicate that the rise has only been of the order of 1 mm. per year. This suggests that the main higher-level ice-caps of Greenland and Antarctica, which together contain more than 90 per cent. of the world's land ice, cannot be melting at the same rate as the local glaciers examined.

Mr. Zobel said that he felt the greatest interest in the paper was in the fundamental cause of the climatic fluctuation, since if this could be discovered, the bare possibility of scientifically sound long-range forecasting occurs. He mentioned briefly the views of Ångstrom, Willett and Brooks, none of whom inclines to the view that climatic fluctuations are caused by changes in the intensity of the long-wave radiation emitted by the sun. Both Ångstrom and Willett consider that such changes are probably due to variations in the ultra-violet band which affect the distribution of pressure and temperature at high levels of the atmosphere and therefore influence the pattern of the general

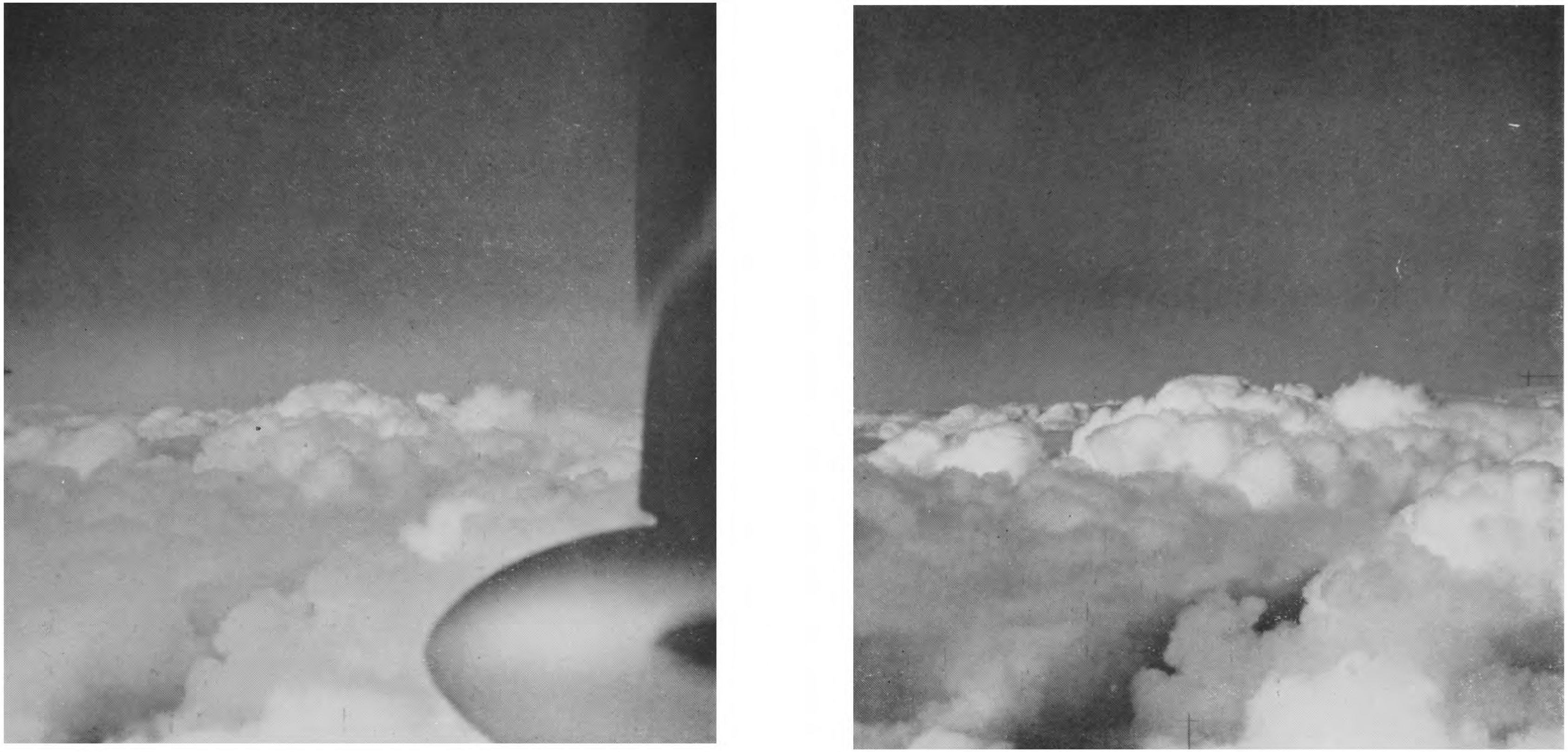

Photo by R.A.F.

1703 B.S.T.

Photo by R.A.F.

1704 B.S.T.

CLOUD FOR DRY ICING

(see p. 10)

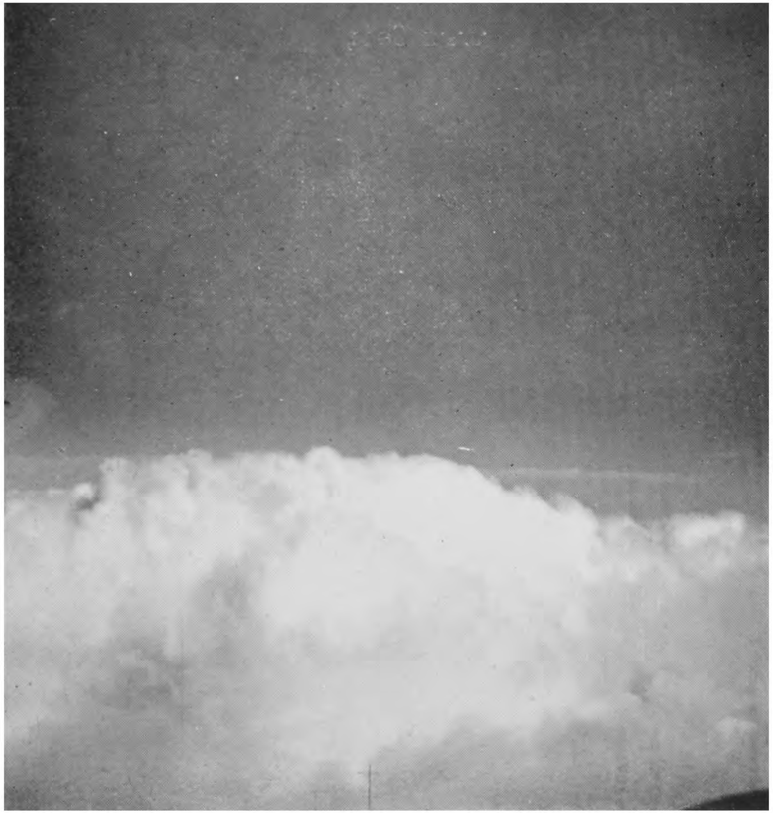

Photo by R.A.F.

1711 B.S.T.
CLOUD FOR DRY ICING
(see p. 10)

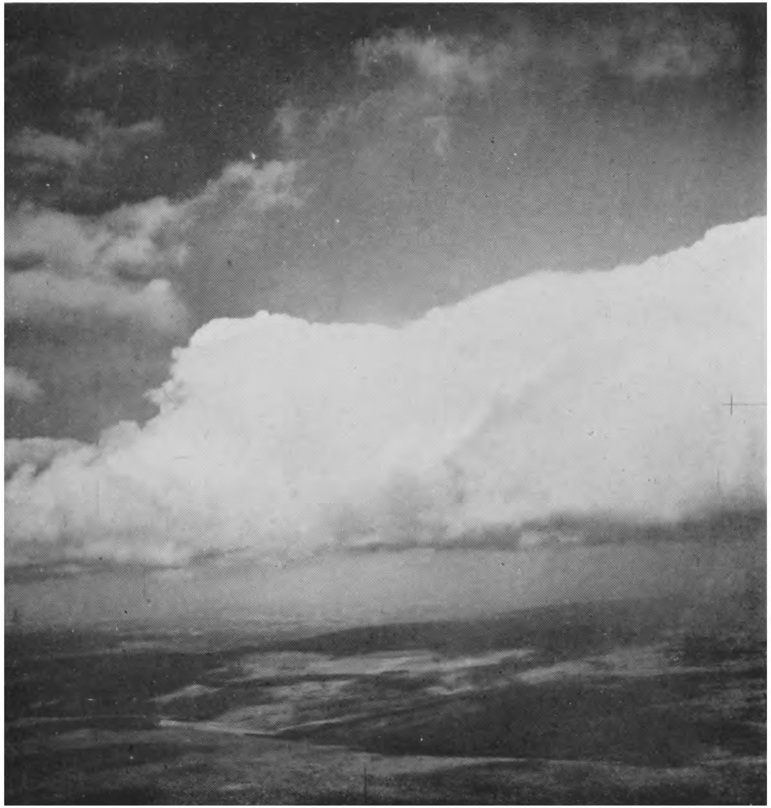

Photo by R.A.F.

1723 B.S.T.
CLOUD-RAIN AFTER DRY ICING
(see p. 10)

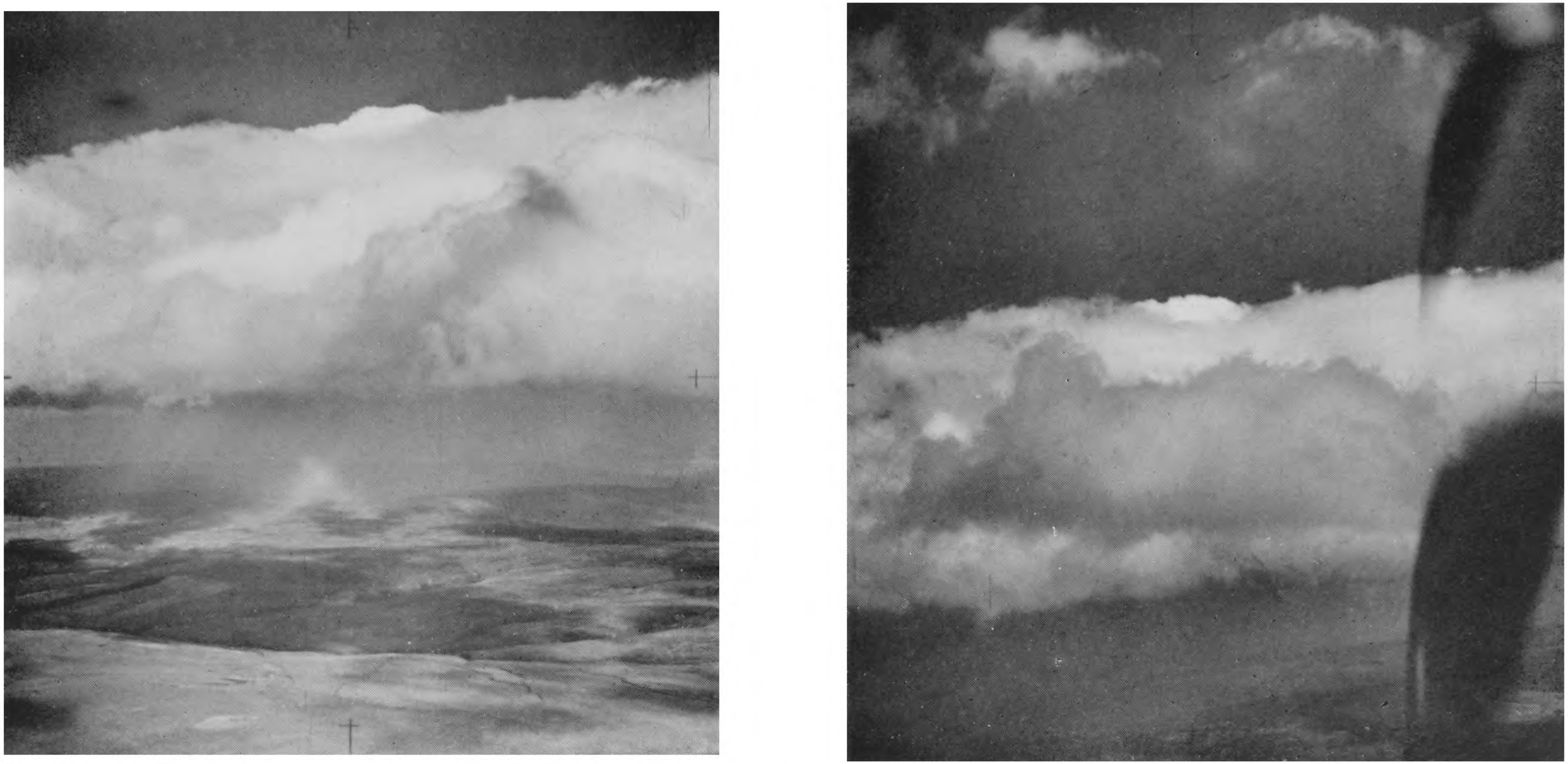

Photo by R.A.F. Photo by R.A.F.

1723 B.S.T. 1730 B.S.T.

CLOUD-RAIN AFTER DRY ICING

(see p. 10)

To face p. 17]

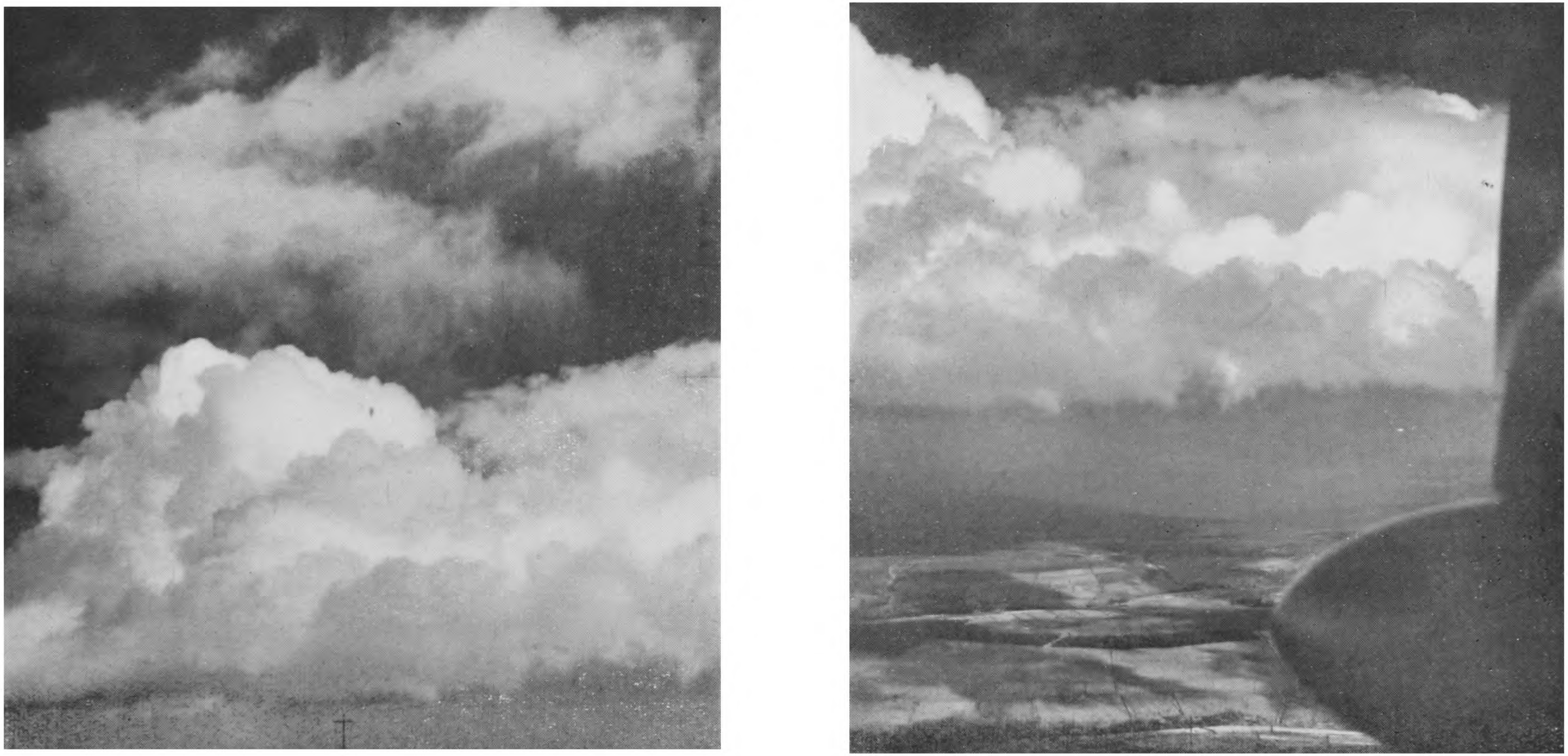

Photo by R.A.F.

1730 B.S.T.

Photo by R.A.F

1730 B.S.T.

CLOUD-RAIN AFTER DRY ICING
(see p. 10)

circulation. On the other hand Brooks considers that minor fluctuations of climate are probably inherent in the atmosphere itself, or in its interaction with the oceans, owing to some process initiated almost by accident in the constant turmoil of depressions and anticyclones, but which, once begun, automatically increases intensity until it becomes unstable or is reversed by some other accident. This view was enlarged upon by Dr. Brooks himself in the discussion which followed the opener's remarks.

The Director pointed out that variations in annual means greatly overshadow the general rise in temperature. He remarked that it is important to take the broad overall view of climatic statistics, since a fall of mean annual temperature of the order of 7–8°C. would be sufficient to produce an ice-age.

Mr. Marshall showed lantern slides illustrating temperature changes in London over the past 100 years. He suggested that the increased winter cyclonic activity in the far north may be associated with a westward extension of the Russian anticyclone, which, when centred over south Scandinavia, would give severe winters in London, as for example in the period 1939–41. His data showed that the most noticeable change had been a fairly steady increase in spring temperatures when computed in 10-year overlapping means. Corresponding winter temperatures showed a similar trend from the period 1899–1908 to the period 1929–38, but during the last decade they had decreased.

Dr. C. E. P. Brooks said that there is no real evidence of a variation of solar radiation during the Christian era. He thought that the atmospheric circulation might not be self-adjusting as generally supposed. During a period of extensive ice in the arctic the " surface pool of cold air " is extensive but shallow, with a strong inversion and warm air above it. This weakens the circulation at 10,000 ft. and through that the surface circulation, and allows the cold conditions to persist. When the arctic is mild the " surface pool of cold air " there is less extensive and less stable; the air above it is relatively cold and a strong circulation is maintained. The Icelandic low is deep and maintains a flow of warm air and water into the arctic. Hence two types of atmospheric circulation are possible under existing conditions of radiation, both persistent, and exceptional conditions are required for a transition from one to the other. Such transitions occurred about the 4th and 11th or 12th centuries. If the present climatic trend continues for another 25 years or so, we may have a third transition, with a return to the warm climatic conditions of Saxon England.

Miss Lewis said the 20-year overlapping means of winter temperatures for Oxford and other places in western Europe showed a fall in the last 10 years, and asked if more recent data than those given by Ahlmann were available for the arctic.

Professor Manley agreed with Miss Lewis that the Oxford record showed a fall of temperature in the winter but the spring had remained warm. The decade 1771–80 with warm summers and cold winters, shown in Dutch and English records, was similar to the last 10 years. It is of interest to compare this fluctuation with other occasions of sudden glacial recessions, notably about 1739, in order to try and forecast its persistence or otherwise. He stated that it is apparent that the existing overall variations could be explained by variations of the vigour of the atmospheric circulation, but more evidence, not only from the past but also from regions such as the North Pacific, is needed in order to indicate the degree of persistence one way or the other.

Mr. Lamb said that it would be wise to admit the possibility of variations in solar energy affecting climate even though this involved the introduction of an " unforecastable " factor. He considered that it might be possible to use data relating to the extent of ice and snow cover, as well as oceanographic data, to predict the broad circulation patterns likely to develop. As an example, he mentioned the fact that the observed warming of the Norwegian Sea over the past 20–30 years has led to an intensification of the thermal gradient off east Greenland. Depressions centred near south Greenland have therefore tended to turn further north, thus leaving room for anticyclones to form over Scandinavia, so producing cold winters over the British Isles concurrent with the highest sea temperatures ever known in the Norwegian Sea.

Cdr. Frankcom suggested that the vast amount of synoptic observations from ships might provide valuable evidence of the global extent of the present climatic fluctuation.

Mr. Bull said that he had found evidence that the rate of climatic change at Jan Mayen had slowed down in the last decade. The mean winter temperature for 1935–44 there was only 0·4°C. above the 1912–30 average, whereas the 10-year means terminating in the 1930's were 2–3°C. above. The Spitsbergen observations were unfortunately too broken in the war years to be of any use.

Dr. Sutcliffe said that he could see no reason why physical meteorologists believe that climatic change must, almost obviously, have an extra-terrestrial cause. He considered that it is quite possible for climate to be largely determined by variations in extent of the ice-caps. These ice-caps might very well grow as a result of snowfall near their boundaries, but eventually the boundaries would be so far displaced as to leave dead ice behind, which in time might wear thin by evaporation or other process, so permitting a sudden jumping of depression tracks to new open waters and a rapid thaw in the resulting westerlies.

Mr. Kirk remarked that it is improbable that changes of climate can be explained without taking the oceanic circulation into account.

Dr. Carruthers referred to the great economic implications which arise as the result of the northward migration of marine animals. In this respect it is important to learn whether the peak of this migration has been passed. Contrary to German opinion, which placed the peak year as 1938, the latest Canadian researches based on studies in Hudson's Bay indicate that the peak has not been passed. He also pointed out that relations between atmospheric circulation and the location of ocean currents such as the Gulf Stream are extremely complex. He felt that the integrated evidence of climatic change provided by agriculture was more reliable than records of sea temperature.

Mr. Gloyne emphasised the reliability of agricultural data in this respect, and remarked that a rise in mean winter temperature of 1°C. would be sufficient to permit grazing in southern England at all times of the year.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Royal Meteorological Society on November 16, 1949, Mr. E. Gold, Vice-President, in the chair, papers were read by Mr. F. Pasquill on a portable apparatus for the study of temperature and humidity profiles near the ground[1]* and on estimates of the amount and diurnal variation of evaporation from clay pasture in spring[2] and by Mr. C. S. Durst on the calculation of departures of wind from the geostrophic value by the use of constant-height balloons[3].

Mr. Pasquill's instrument is designed to measure the temperature and humidity at six levels, 25, 37·5, 50, 100, 150 and 200 cm. above the ground. It consists essentially of six horizontally-mounted modified Assmann psychrometers with thermocouple elements to facilitate distant reading. The elements are placed in horizontal tubes leading into a hollow aspiration mast about seven ft. long. Air is drawn past the elements by a fan at the top of the aspiration mast. The apparatus is made as far as possible of standard moulded-plastic tubes. Shields were provided to reduce radiation errors and the bushes were inserted in the side tubes to give a constant rate of aspiration of 2·5 m./sec. in all of them as is necessary owing to the variation of the psychrometric " constant " with rate of airflow past the bulb. The thermometric elements were deliberately given substantial thermal inertia and the lag coefficient was 1 minute for the wet and 2 minutes for the dry bulb. Some examples of temperature and humidity profiles were shown, giving very smooth curves.

Mr. Pasquill drew attention to an evaporation formula used by Thornthwaite and Holzman[4] but the validity and limitations of this had only recently been directly tested. This formula, applicable only to the flow of an adiabatic atmosphere over an aerodynamically rough surface is

$$E = \rho \frac{K^2 (q_1 - q_2)(u_2 - u_1)}{(\log_e z_2/z_1)^2}$$

where E is the rate of evaporation, q_1, q_2 and u_1, u_2 are the specific humidities and wind velocities at heights z_1, z_2, ρ is the air density and K is Karman's " constant ", here of magnitude 0·4.

Appealing to a previous demonstration of " virtual adiabaticity " near the surface in non-adiabatic conditions, Mr. Pasquill then applied a simplified form of the above formula in evaluating evaporation from hourly observations of wind velocity and vapour pressure at 50 cm. and 25 cm. He showed curves of wind velocity, U_{50}, vapour-pressure difference, $e_{25}-e_{50}$, and the computed values of E in 10^{-5} gm./cm.^{2}/sec. taken over an exposed clay pasture near Cambridge from May 7 to 13, 1947. Both velocity and vapour-pressure difference showed a marked diurnal variation with maximum values about midday so the evaporation, proportional to their product, showed an even more marked diurnal variation. Negative values of the vapour difference and consequently of the evaporation occurred over several hours on some nights and during these periods dew was observed to form. He considered that his method gave the evaporation with an accuracy of mainly 10 per cent. rising to 20 per cent. in the unstable conditions of midday. The total daily evaporation found by integrating the curves varied between 1·4 and 3·6 mm. Mr. Pasquill concluded by pointing out that it was essential to employ hourly values of wind velocity and vapour-pressure difference for computing evaporation, and that the use of mean daily values in the formula would give an underestimation of about 50 per cent.

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*These index numbers refer to the list of references on p. 21.

Dr. Penman said he was considering the installation of a rather similar apparatus at Rothamsted, but he was using unaspirated elements and varying the psychrometric constant to suit the ventilation as he thought aspiration at 2·5 m./sec. would bring in air from levels above and below the desired one. He went on to question several aspects of the theory of turbulence in its application to evaporation such as the assumed constancy of shearing stress and of Karman's " constant ". Evaporation from tanks did not agree with Pasquill's results.

Prof. Sheppard said that if tank evaporation results did not agree it was because tanks were not the same as the ground. He emphasised that the turbulent-flow formulae were really empirical.

Mr. Lapworth would like to see the formula tested by installing Pasquill's apparatus over a tank, and also some method of using it without such frequent observations.

Dr. Glasspoole said evaporation measurements at Valentia in 1930 showed evaporation going on throughout day and night, the night value being about half that during the day. He pointed out that water engineers would like a higher order of accuracy than 10 per cent. which was a large error for evaporation from a reservoir.

Dr. Robinson said that at Kew there was a near copy of Pasquill's apparatus close to an evaporation tank, and it was found that the tank gave the same value of evaporation in daylight so long as the grass was in good condition, but at night the tank goes on evaporating when the ground appears to stop.

Dr. Sutcliffe said it would be useful if the fall of dew, on which there was little information, could be given from Mr. Pasquill's curves. He thought the formula rather doubtful as he was sure dew would fall at night or evaporation take place in a flat calm, but perhaps Karman's constant became indeterminate then.

Mr. Pasquill in reply said the evaporation formula does not apply to tanks, over which there was stable air. With regard to aspiration errors of the apparatus he described trials which satisfied him that there was no significant sucking of air from other levels. Though the observational justification of the formula had so far been confined to evaporation, as distinct from condensation, he saw no reason why it should not apply to the latter within the limits of departure from adiabatic conditions and so gives dewfall by integrating the appropriate sections of the curves.

Mr. Durst said that, following a suggestion by himself and Prof. Sheppard, balloons carrying constant-height apparatus were followed by radio direction finding on seven occasions in 1943 and 1944 in order to compare the measured departure of the wind from the geostrophic with the departure to be expected by calculation from the observed acceleration. The balloons were made to follow a predetermined pressure level about 400 or 500 mb. by controlling the escape of gas or by jettisoning sand or fluid. The departure is, theoretically and neglecting friction, a vector to the left of and at right angles to the acceleration and having a proportion $1/2\ \omega \sin \phi$. The horizontal acceleration was measured from the observed track of the balloon and the term in the total acceleration arising from the vertical component of air motion was determined by using the variation in wet-bulb potential temperature at the balloon to give the vertical component and by obtaining the vertical wind gradient from the routine soundings. From values of the total acceleration so obtained corresponding theoretical values of the geostrophic departure of the wind were calculated and compared with geostrophic departures calculated from a comparison between the routine soundings at Larkhill, Fazakerley and Downham Market with the geostrophic winds given by specially drawn contour charts. One of the flights had been omitted from consideration because the balloon passed through a front. Agreement between the calculated and computed departures was good in both direction and magnitude. Another method of finding the total acceleration by constructing trajectories from the 500-mb. contour charts did not give satisfactory values of the geostrophic departure possibly because the trajectories had to be smoothed over 36 hours. This suggests that geostrophic departures are not associated with major depressions and anticyclones but with small-scale irregularities. The balloon tracks were also used to find eddies in the wind and gave evidence of fluctuations of wind of the order of 3 or 4 kt. from one half-hour to another.

Prof. Sheppard, *Dr. Sutcliffe*, *Mr. Matthewman*, *Mr. Craddock* and *Dr. Robinson* contributed to the discussion in which questions were asked about the balloon which floating with the air managed to pass through a front and the relation of the eddies to deviations from the geostrophic wind. Mr. Durst replying, said he thought vertical motion of the balloon relative to the air carried it through the front and that the eddies were short-period affairs compared with the geostrophic deviations which were measured over hours.

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2. PASQUILL, F.; Some estimates of the amount and diurnal variation of evaporation from a clayland pasture in fair spring weather. *Quart. J. R. met. Soc., London*, **75**, 1949, p. 249.
3. DURST, C. S. and GILBERT, G. H.; Constant-height balloons—calculation of geostrophic departures. *Quart. J. R. met. Soc., London*, **76**, 1950.
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OFFICIAL PUBLICATION

The following publication has recently been issued:—

METEOROLOGICAL REPORTS

No. 3—Theoretical aspects of pressure-pattern flying. Compiled by J. S. Sawyer, M.A.

The techniques of pressure-pattern flying apply meteorological knowledge to air navigation. The most important methods (*a*) compute drift from radar altimeter observations, (*b*) enable flights to be made with a constant heading of the aircraft, and (*c*) indicate tracks which are quicker and more economical than the direct route.

In this report the theoretical basis of these methods is explained and the relevant meteorological factors are examined in detail. Particular attention is given to the accuracy which may be expected in pressure-pattern navigation and to the limitations to which the methods are subject.

LETTERS TO THE EDITOR

Frequency distribution of wind speed in synoptic reports

One of the changes in the code for synoptic reports of surface observations, about which there was most discussion and difference of opinion in the meetings of the Commission for Synoptic Weather Information at Paris in 1946, and Toronto in 1947, was the provision of two figures for wind speed.

I thought, therefore, it would be interesting to see how the values of wind speed (in knots) now published in the British Section of the *Daily Weather Report* were distributed. Reports are published for 61 stations for the four principal hours of observation, 0000, 0600, 1200 and 1800 G.M.T. The values are obtained from anemometers except for ten stations where they are estimated with the same aids as those used when the force was estimated on the Beaufort Scale. Five stations do not report at 0000 G.M.T. and there were a few other omissions.

I prepared frequency tables from the values in the 11 *Daily Weather Reports* for October 18–28, 1949, one table for the anemometer stations (A.) and another table for the non-anemometer stations (N.A.). They are reproduced below up to 40 kt. There were a few observations above 40 kt. but not enough to warrant extension of the tables. The period began with a deep depression and general gales and ended with an anticyclonic ridge and general calms and light airs. The range of speeds was therefore a wide one.

TABLE I—FREQUENCIES OF WIND SPEED, OCTOBER 18–28, 1949

A. = anemometer station values
S.A. = smoothed anemometer station values
N.A. = non-anemometer estimates

Speed	A.	S.A.	N.A.	Speed	A.	S.A.	N.A.	Speed	A.	S.A.	N.A.	Speed	A.	S.A.	N.A.
kt.				kt.				kt.				kt.			
0	116	116	8												
1	19	33	1	11	56	104	3	21	30	46	2	31	10	16	—
2	50	41	14	12	117	96	2	22	40	42	—	32	14	12	—
3	55	52	3	13	78	87	30	23	43	39	—	33	5	8	2
4	50	62	3	14	68	88	—	24	31	38	12	34	2	7	—
5	87	73	32	15	127	85	1	25	48	36	—	35	15	7	—
6	74	83	7	16	61	77	5	26	31	30	—	36	4	6	2
7	91	94	6	17	47	68	1	27	15	23	2	37	2	4	8
8	118	110	5	18	94	65	3	28	19	20	—	38	4	3	—
9	102	115	36	19	32	59	10	29	11	19	—	39	2	2	—
10	175	120	5	20	85	57	—	30	36	20	7	40	2	2	5

There are some features in the tables which leap to the eye and are not difficult to explain. But there are others which are less obvious.

For the A. stations the principal feature is the preponderance of the tens and fives. The average frequency of occurrence of one of the ten digits is 195. But the frequency of the noughts (excluding the calms) is 298 and of the fives, 277. The greater number of noughts than of fives is due to the fact that the maximum frequency is near to 10 kt.

The frequency of occurrence of the other digits is as follows:—

Digit	1	2	3	4	6	7	8	9
Frequency	115	221	181	151	170	155	235	147

It is difficult to see a satisfactory explanation of the outstanding maxima at digits 2 and 8. There is, on the whole, a preference for even numbers. The total for the even digits is 777 and for the odd 598; if 0 and 5 are included the totals are 1075 and 875 respectively.

Of individual values, apart from the noughts and fives, the most outstanding is the frequency of 18 kt., *viz.* 94, more than double the frequencies of 17 or 19 kt. and greater even than the frequency of 20 kt. Outstanding also is the low frequency of 1 kt., but this is perhaps less surprising than the equality of frequencies of 2, 3 and 4 kt.; the standard anemometers are not very sensitive at these low speeds and an uneven distribution might have been anticipated.

The fact that the frequency of calms does not fit into the series is not surprising. Calms form a quite separate category independent of the unit used, whereas the other frequencies would be doubled if metres per second were used in the classification instead of knots.

Clearly many of the reports of 10 kt. should have been of 9 or 11 kt. and some 8 or 12 kt., and similarly for the other tens and the fives. In order to see what the correct distribution of frequencies should be, I have tried smoothing the A. series by several formulae. The best appears to be $(a+2b+3c+2d+e)/9$. This is the same as forming a new series by the formula $(a+b+c)/3$ and then smoothing the new series by the same formula $(a+b+c)/3$. The first smoothing eliminates the error due to preference for even numbers and part of the error due to preference for noughts and fives. The second smoothing practically completes the elimination of the latter error. The smoothed values are given under the heading S.A. The frequency of calms is not used in deriving the smoothed values. The first value is derived by giving b and c the frequency of " 1 ", a and d the frequency of " 2 " and e the frequency of " 3 ". For the second value, a and b both have the frequency of "1 ". The smoothed frequencies when plotted, lie fairly well on a smooth curve. Thus, statistically, the reports provide a fair representation of the distribution of wind speed. But synoptically they fail to provide the sound basis for close investigations which the protagonists of " two figures " for wind speed hoped. To achieve that, observers must discontinue the facile throwing of nines and ones to zero and of fours and sixes to fives.

The values for the N.A. stations congregate about the speeds at a height of 10 m. corresponding with the Beaufort numbers. This is broadly what was expected, though it was hoped there would be a substantial number of reports midway between these equivalents.

E. GOLD

8 *Hurst Close, London, N.W.*11, *November* 3, 1949

[Similar results have been reported for other measurements, see Yule, G. U. and Kendall, M. G., An introduction to the theory of statistics. 13th edn. London, 1947, p. 86.—Ed. *M.M.*]

Radio-sonde ascent into cumulonimbus cloud

At the 2100 G.M.T. routine sounding on July 16, 1949, the radio-sonde launched from Camborne entered a cumulonimbus cloud and had an abnormal rate of ascent from 800 mb. to 350 mb.

The normal rig, consisting of a 500-gm. balloon, parachute, radar reflector, and radio-sonde transmitter was used. The balloon was inflated to give a free lift of 3,400 gm. which would normally have given a mean rate of ascent of 1,200–1,300 ft. min. from the surface to 400 mb. The balloon was launched at 2000 G.M.T., and at that time the weather was cloudy with a moderate shower of rain. The cloud was 8 oktas cumulonimbus with a ragged and ill-defined base.

The rates of ascent for each 100-mb. layer from the surface to 300 mb. were:—

Layer	Surface–900 mb.	900–800 mb.	800–700 mb.	700–600 mb.	600–500 mb.	500–400 mb.	400–300 mb.
			ft./min.				
Rate of ascent	929	1454	1971	1673	2095	3397	1483

The heights obtained from the radar set confirm these rates of ascent. From 350 mb. to the burst at 98 mb. the rate of ascent was normal.

The temperatures obtained from this sounding are probably too warm between 600 mb. and 400 mb. because of the excessive rate of ascent and the consequent lag in the temperature unit. Between 400 mb. and 370 mb. the lapse rate recorded was 10·2°F./1,000 ft., and this is also considered to be due to the lag in the temperature unit.

G. A. JEFFREY

Kehelland, Camborne, Cornwall, August 18, 1949

Flight through cloud funnel of waterspout

During March 1949 a Harvard aircraft sighted a waterspout off the north-east corner of Singapore Island and deliberately flew through the cloud funnel. Unfortunately the observer did not report the fact at the time and the value of his observations is reduced by the lapse of six months before being recorded. However, in view of the rarity of such observations they are detailed below:—

Observer—F/Lt. Brain, Far East Communications Squadron.

Position—Over sea just off the eastern tip of Pulau Ubin, an island off the coast of north-east Singapore.

Time—0130 to 0230 G.M.T. March 14, 1949.

Weather—Cloudy, scattered showers, none appearing to be heavy or of any great extent. Main cloud base 2,000–3,000 ft.

The pilot was flying at 1,500 ft. when his attention was drawn to a cloud darker than the rest with cloud base about 1,200 ft. From this cloud the funnel of a waterspout was already to be seen meeting the sea surface. The pilot descended to 600 ft. From this position he estimated the diameter of the spout as 3–5 ft. where it met the sea and about 70 ft. at his level, widening gradually as it met the cloud base. The two ends of the funnel were relatively fixed while the middle writhed convulsively. Flying in clear air at 600 ft. turbulence was light and the funnel appeared to be totally composed of cloud. There was no precipitation at the time.

The pilot entered the cloud funnel at 600 ft. and for a short period the aircraft was completely enveloped. There was no appreciable increase in turbulence caused by passing through the cloud funnel and no apparent precipitation, nevertheless the aircraft emerged wet all over. On turning back to look at the funnel a few seconds later, it had apparently been unaffected by the passage of the aircraft.

The observer could not remember any facts about rotation or disturbance of the sea surface.

Weather observations at Changi at the time gave large cumulus but no showers until 0935, though thunder was first heard at 0915 that day.

P. E. PHILLIPS

Changi, Singapore, September 29, 1949

Lightning display at Ramsgate

The display of lightning, which I observed in the vicinity of Ramsgate between 1930 and 2030 G.M.T. on September 23, 1949, was, I think, unusual for this country. The centre of the storm lay to the south-west of Ramsgate and moved northwards. The sky was overcast with medium and high cloud and only towards the end of the period did low cloud at about 3,000 ft. develop. A few drops of rain fell intermittently.

At intervals of a few minutes a lightning stroke appeared from the south-west or west at an angle of about 40 degrees from the horizon. Most of the strokes lengthened to the zenith by, what seemed to be, a series of discrete steps, while branches from both sides of them moved outwards and lengthened in jerks. One stroke to the south-west did not lengthen to the zenith but branches sprang from it radially increasing in length in a similar way. Owing to the poor vertical visibility the illumination of the discharges was not so intense as to hinder me from observing them. The thunder associated with the discharges was heard first overhead at about 10 sec. after the flash was seen and was not loud. When later the low cloud developed only sheet lightning could be seen.

J. E. BELASCO

Harrow, October, 1949

[The phenomenon seen by Dr. Belasco appears to have been the rare phenomenon " rocket lightning " as described by Simpson (*Proc. roy. Soc., London,* A, **111**, 1926, p. 66) and Humphreys (" Physics of the air " New York and London, 3rd edn. 1940, p. 368). The storms of September 23 were particularly violent over north-west France. According to an article in *Figaro* hailstones weighing 650 gm. fell near Lisieux, Normandy.—Ed. *M.M.*]

NOTES AND NEWS

The Bilham humidity slide-rule, Mk. III

As was foreshadowed in an article by Mr. R. H. Collingbourne in the *Meteorological Magazine,* November 1948, a new model of the humidity slide-rule has been designed in order to furnish values of relative humidity and dew point with respect to saturation over water at all temperatures. The opportunity has been taken to extend the scales to very low temperatures so that the new slide-rule will be able to handle not only surface observations made in high latitudes but also upper air observations made by aircraft or by radio-sonde. The new rule will be known as Mk. III and will replace the earlier models Mk. I and Mk. II. Production is in hand and we hope to publish an article by Mr. E. G. Bilham giving full details in an early issue of this Magazine.

Photographs for new International Cloud Atlas

A small committee was formed by the International Meteorological Organization to produce a new International Cloud Atlas, with M. A. Viaut, Director of the French Meteorological Office, as President. The present Atlas was first published in 1932 and reprinted in 1939. The committee had its first meeting at Paris in August 1949.

The selection of photographs taken from the ground to illustrate the new Atlas is nearly complete, but there are still some gaps to be filled in respect of certain special forms. A recent circular letter from the President of the Committee asks for photographs taken in tropical and polar regions, and also for illustrations of special forms such as:—

Nacreous clouds
Luminous night clouds
Clouds produced by fires, volcanoes, waterfalls, etc.
Fog and mist
Phenomena due to sand, dust, or drifting snow
Condensation trails, artificial rain, artificial dissipation of clouds or fog
Clouds of insects (*e.g.* locusts)
Optical phenomena in clouds (haloes, coronae, etc.).

Photographs procured by unusual methods such as whole-sky photographs, infra-red, radar, V-2 rockets, etc., are also wanted.

The date, time and place of photographs should be noted, also the direction and approximate elevation of the photograph, and descriptive notes on the clouds and on any related feature of interest would be useful. Notes can conveniently be written on the backs of the prints, provided that nothing shows through to the other side. Enlarged prints are best, and obviously only photographs of a high technical standard have any chance of inclusion in the Atlas.

Colour photographs, on films or plates, would be particularly appreciated. If possible the size should be larger than the standard 24 × 36 mm.

The selection of cloud photographs from the air (or of photographs from mountains of clouds below the observer) has not yet been carried out. Though the number of cloud photographs from the air is now large, there is still a difficulty in finding suitable illustrations of some forms, especially of high clouds and altostratus. There is a natural tendency to concentrate on the more striking cloudscapes, so that clouds with poorly defined tops, and smooth or featureless layers which are not easy to photograph cannot yet be adequately illustrated. Whenever it is technically possible in such cases to obtain a photographic representation of what the observer sees, the result would be of scientific value even if it looks featureless.

Photographs are asked for taken from above, from below and from the side of clouds, at various angles, *e.g.* vertical, inclined and horizontal.

Photographs can be sent to me at the Central Forecasting Office, Dunstable, Beds., for forwarding to the Committee, and in the case of photographs taken over or near the British Isles, western Europe or the Atlantic, I can add the notes on the synoptic situation and the vertical atmospheric structure, which are asked for in the circular letter. They are wanted by March if possible, and at latest by the time the Committee meets next summer, probably in June.

C. K. M. DOUGLAS

Frequencies of tropopause temperatures over Larkhill from June 1945 to December 1947

The frequencies of different tropopause temperatures over Larkhill given in the table below were extracted from summaries held in the Climatological Division.

SUMMARY OF TEMPERATURES AT THE TROPOPAUSE FOR LARKHILL

JUNE 1945 TO DECEMBER 1947

Temperature	Dec.–Feb.	Mar.–May	June–Aug.	Sept.–Nov.
°F.	*Number of occasions*			
−109, −108	1			
−107, −106	1			
−105, −104	1			
−103, −102	4			1
−101, −100	8			
−99, −98	13	1		3
−97, −96	14			9
−95, −94	15	1		12
−93, −92	26	3		11
−91, −90	28	9	2	20
−89, −88	38	10	2	37
−87, −86	38	18	2	32
−85, −84	49	32	12	37
−83, −82	50	32	15	50
−81, −80	47	34	22	78
−79, −78	44	46	29	85
−77, −76	35	54	53	83
−75, −74	43	61	52	73
−73, −72	39	55	75	82
−71, −70	43	48	87	63
−69, −68	44	45	83	54
−67, −66	39	45	86	45
−65, −64	31	39	80	40
−63, −62	28	26	68	34
−61, −60	27	21	69	34
−59, −58	23	21	52	33
−57, −56	24	22	54	22
−55, −54	9	16	32	18
−53, −52	7	8	29	16
−51, −50	11	6	25	10
−49, −48	7	6	15	9
−47, −46	3	4	14	4
−45, −44	4	2	15	4
−43, −42		3	6	5
−41, −40		1	7	2
−39, −38		2	3	
−37, −36			2	
−35, −34			3	
−33, −32			1	
	degrees Fahrenheit			
Mean	−77·2	−71·0	−65·2	−73·3
Standard error of mean	1·5	1·3	1·0	1·1
Total number of observations	Dec. 342 Jan. 239 Feb. 213	Mar. 231 Apr. 207 May 233	June 326 July 331 Aug. 338	Sept. 321 Oct. 354 Nov. 331
	794	671	995	1,006

The table gives seasonal frequencies of tropopause temperatures irrespective of the height of the tropopause. Frequencies for the three types of tropopause and for the four daily ascents (normally at 0000, 0600, 1200, 1800 G.M.T.) have been combined. Means and standard errors of means are also given. The standard error of the mean has been taken as $\surd(\text{variance} \div n/3)$ where n is the number of days in the period. Investigations by Brooks and Carruthers into the effect of persistence in meteorological data have shown that, in general, observations of temperature on n consecutive days are roughly equivalent to $n/3$ independent observations. The factor 3 is used by Carruthers* in a discussion of the accuracy of mean values of temperature. Frequencies in this table are based on four observations a day so 12 observations have been taken as equivalent to only one independent observation. This is possibly an over-estimate of the dependence and so the true mean probably departs from the sample mean by a slightly smaller value than that given for the standard error. It has been considered of more value to give standard errors of the mean than standard deviations as the distributions are clearly not normal.

D. DEWAR

Geophysical prospecting below the bed of the deep sea

The Department of Geodesy and Geophysics of Cambridge University carried out experiments from the Ocean Weather Ship *Weather Explorer* at Station JIG, during August 1949. These experiments employed a new technique of seismic prospecting developed for use in the deep sea.

The shock waves necessary in such prospecting were obtained from standard Naval depth charges set to fire at 150 fathoms. These waves travelled by different routes to hydrophones positioned 20 fathoms below Sono-Radio Buoys which transmitted the information back to the ship.

By analysing the sound travelling through the ground for distances between charge and buoy varying between 6 and 20 miles, it is possible to determine the thicknesses of the various layers constituting the sea bed. The preliminary analysis shows that the soft sediments are about 7,000 ft. thick, and that below the sediments is a layer about 9,000 ft. thick which consists of a hard rock similar to that lying a few thousand feet below the continents. The rock below this again extends to a depth which cannot be determined from the results, but of which the composition is similar to that supposed to exist at a depth of some 40,000 ft. below the continental surface.

REVIEW

British thunderstorms 1949, May 14–16. Prepared by the Thunderstorm Census Organization. Research Publication 49/15. Chart 37¼ in. × 39¾ in. Huddersfield, 1949.

Series of charts are prepared by the Thunderstorm Census Organization showing the main overhead storm areas and principal damage areas. Additionally strokes to earth outside damage areas are separately depicted and isochrones of the storm centres are shown hourly.

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*CARRUTHERS, N; The accuracy of a mean of n temperature observations as an estimate of the mean temperature for a particular month. *Met. Mag., London*, **78**, 1949, p. 65.

These charts meet several of the primary needs of Electrical Research Authorities* in that they show the approximate time when the storm is overhead at a given point and the isochrones show the general direction of movement. Further, the severity of the storm is brought out quite well by the charting of the principal damage areas, and by the records of strokes to earth, although of course these latter are unlikely to be fully representative over sparsely populated areas.

The charts themselves are on a scale of 10 miles to the inch and show the administrative county divisions in outline; the elements set out above are plotted in black. The chart for May 14–16, 1949, has been sent for review and an immediate criticism is that this period has more than one series of storms on different days over the same areas; this has made the chart difficult to read, it would therefore seem that these charts are best restricted to one 24-hour period for each chart, unless storm areas do not overlap. Other charts restricted to a single day have been seen and an extremely clear picture of the thunderstorm activity of the day is depicted and the damage areas stand out most clearly; the chart also has inset a selection of relevant upper air ascents extracted from the *Daily Weather Report.*

BOOKS RECEIVED

L'action individuelle des taches solaire sur les phènomenes terrestres, by H. Mémery. Size: 9 in. × 6¼ in., pp. 40. Observatoire de Physique solaire et de Météorologie. Talence (Gironde), 1948.

Precipitation affected by solar radiation, by C. G. Abbot. *Smithson. misc. Coll.* **107**, No. 9. Size: 9½ in. × 6¼ in., pp. 4. Smithsonian Institution, Washington, D.C. 1947.

THE WEATHER OF NOVEMBER 1949

Mean pressure was about 996 mb. south-westward of Iceland. It was between 1020 and 1025 mb. in and around the Azores and in the U.S.A. over an area including most of Oregon, Idaho, Utah and Nevada.

November 1949 was the first month since August 1948, with the exception of May 1949, in which mean pressure was below normal over most of Europe. The deficiency extended from the central Mediterranean north-westwards across central Europe and the British Isles to Iceland and from there westwards and south-westwards to most of North America and amounted generally to between 5 and 8 mb. Mean pressure was above normal north-eastward of Iceland, in northern Norway and in Sweden (by 10 mb. at Harparanda) and also over a considerable area centred near the Azores.

In the British Isles the weather of November was unsettled, wet on the whole (although there was a large area in central and north Scotland with less than the average rainfall) and rather mild.

During the opening days a wedge of high pressure over the southern districts of the British Isles moved slowly south, while troughs of low pressure associated with a depression near Iceland moved across the northern districts. Rather cold, fair weather, apart from mist and fog, prevailed in the south-east, while rain occurred at times in the west and north. Subsequently very unsettled con-

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*See 1. GOLDE, R. M.; Thunderstorm observations. *Met. Mag., London,* 77, 1948, p. 49.
2. BOWER, S. M.; Thunderstorm observations. *Met. Mag., London,* 77, 1948, p. 207.
3. GOLDE, R. M.; Thunderstorm observations. *Met. Mag., London,* 77, 1948, p. 208.

ditions set in and persisted until the 13th. On the 4th a small depression developed in mid Atlantic and moved rapidly north-east deepening as it moved. In the British Isles, rain, heavy in places, occurred on the 4th and 5th, while winds were strong, reaching gale force. Rainfall on the 4th amounted to 2·99 in. at Glenquoich, Inverness-shire and 2·47 in. at Blaenau Festiniog, Merioneth, on the 4th. On the 6th another depression developed in mid Atlantic and moved quickly south-east to France; this also deepened as it moved and there were showers with local hail and thunder in the British Isles. Again on the 8th and 9th a deep Atlantic depression moved north-east to the south-west of Iceland and then turned east; rain occurred fairly generally and winds were strong, while gales were experienced at exposed places in the west. On the 11th a disturbance off north-west Ireland moved east-north-east, while associated troughs moved east; widespread gales occurred on the 12th when a strong WNW. gale affected the Bristol Channel; a ship was wrecked off Lundy on the 13th and many of the crew were drowned. Rainfall was heavy locally in the north-west and thunder occurred in some places (for example, 3·44 in. at Troutbeck and 3·26 in. at Watendlath Farm, in Cumberland). An improvement (apart from fog) took place in eastern districts on the 14th and 15th with the eastward passage of a wedge of high pressure, but a trough over western districts caused further rain there. Subsequently the trough moved very slowly east giving more rain in the western half of the country on the 16th and general and rather heavy rain on the 17th, with gales in the west and north. Thereafter another less vigorous trough moved slowly east over the country; rain or showers occurred, the rainfall being moderately heavy on the 20th. By the 21st a new deep depression was situated west of Scotland, where it remained almost stationary until the 23rd, while troughs moved over the British Isles. Showery weather prevailed, with bright periods locally and gales at exposed stations. On the 23rd the main depression moved a little east and filled while a small secondary off south-west Ireland moved to France and became less deep. Subsequently a complex area of low pressure was established over France and the south Baltic. Rain occurred at times in most parts of the British Isles, being heavier on the east coast of Britain; it was mainly dull, with NE. to N. winds. Thereafter a ridge of high pressure associated with an anticyclone on the Atlantic moved south over this country on the 28th and 29th. Meanwhile depressions in the far north moved north-east or east. Occasional rain occurred in the north but only slight, scattered rain in south. Some sunny periods were recorded at most stations on the 28th, in the south on the 29th and in the south-west also on the 30th.

The general character of the weather is shown by the following provisional figures:—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	62	21	+0·9	125	+2	99	23
Scotland	58	13	+1·7	111	+2	88	19
Northern Ireland ..	57	26	+1·0	101	0	104	26

RAINFALL OF NOVEMBER 1949

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	2·15	91	*Glam.*	Cardiff, Penylan ..	4·77	118
Kent	Folkestone, Cherry Gdns.	4·57	141	*Pemb.*	St. Ann's Head.. ..	5·19	130
,,	Edenbridge, Falconhurst	3·66	103	*Card.*	Aberystwyth	6·90	187
Sussex	Compton, Compton Ho.	4·79	126	*Radnor*	Tyrmynydd	8·64	130
,,	Worthing, Beach Ho. Pk.	3·47	108	*Mont.*	Lake Vyrnwy	8·26	142
Hants.	Ventnor, Roy. Nat. Hos.	3·93	122	*Mer.*	Blaenau Festiniog ..	11·02	103
,,	Bournemouth	3·82	112	*Carn.*	Llandudno	3·10	107
,,	Sherborne St. John ..	3·09	108	*Angl.*	Llanerchymedd ..	4·49	107
Herts.	Royston, Therfield Rec.	2·54	109	*I. Man.*	Douglas, Borough Cem.	4·77	101
Bucks.	Slough, Upton	2·27	102	*Wigtown*	Port William, Monreith	4·09	95
Oxford	Oxford, Radcliffe ..	2·52	110	*Dumf.*	Dumfries, Crichton R.I.	5·16	140
N'hant	Wellingboro', Swanspool	2·19	102	,,	Eskdalemuir Obsy. ..	6·62	114
Essex	Shoeburyness	2·02	95	*Roxb.*	Kelso, Floors	2·88	125
Suffolk	Campsea Ashe, High Ho.	2·16	97	*Peebles.*	Stobo Castle	4·16	126
,,	Lowestoft Sec. School ..	2·23	95	*Berwick*	Marchmont House ..	3·24	108
,,	Bury St. Ed., Westley H.	2·15	93	*E. Loth.*	North Berwick Res. ..	3·09	138
Norfolk	Sandringham Ho. Gdns.	2·71	109	*Midl'n.*	Edinburgh, Blackf'd. H.	3·51	157
Wilts.	Bishops Cannings ..	2·91	102	*Lanark*	Hamilton W. W., T'nhill	3·73	104
Dorset	Creech Grange ..	4·07	99	*Ayr*	Colmonell, Knockdolian	4·66	93
,,	Beaminster, East St. ..	4·77	120	,,	Glen Afton, Ayr San. ..	7·78	141
Devon	Teignmouth, Den Gdns.	4·56	143	*Bute*	Rothesay, Ardencraig ..	6·94	137
,,	Cullompton	5·13	149	*Argyll*	L. Sunart, Glenborrodale	9·85	132
,,	Barnstaple, N. Dev. Ath.	3·60	92	,,	Poltalloch	8·93	159
,,	Okehampton, Uplands	6·62	124	,,	Inveraray Castle ..	10·52	125
Cornwall	Bude School House ..	4·95	139	,,	Islay, Eallabus		
,,	Penzance, Morrab Gdns.	4·98	109	,,	Tiree	7·40	153
,,	St. Austell	6·81	138	*Kinross*	Loch Leven Sluice ..	3·80	106
,,	Scilly, Tresco Abbey ..	5·10	148	*Fife*	Leuchars Airfield ..	2·37	103
Glos.	Cirencester	2·94	99	*Perth*	Loch Dhu	8·57	99
Salop	Church Stretton ..	3·67	118	,,	Crieff, Strathearn Hyd.	3·57	82
,,	Cheswardine Hall ..	2·73	105	,,	Pitlochry, Fincastle ..	3·67	99
Staffs.	Malvern, Free Library	3·04	121	*Angus*	Montrose, Sunnyside ..	3·57	135
Worcs.	Birmingham, Edgbaston	3·26	137	*Aberd.*	Braemar	3·95	103
Warwick	Thornton Reservoir ..	3·34	148	,,	Dyce, Craibstone ..	5·06	155
Leics.	Boston, Skirbeck ..	2·43	122	,,	Fyvie Castle	3·63	105
Lincs.	Skegness, Marine Gdns.	2·10	97	*Moray*	Gordon Castle	2·45	85
,,	Mansfield, Carr Bank ..	3·07	126	*Nairn*	Nairn, Achareidh ..	2·59	115
Notts.	Buxton Terrace Slopes	6·78	145	*Inv's*	Loch Ness, Foyers ..	2·90	74
Ches.	Bidston Observatory ..	3·80	152	,,	Glenquoich	11·81	97
Lancs.	Manchester, Whit. Park	4·65	176	,,	Fort William, Teviot ..	8·47	103
,,	Stonyhurst College ..	4·92	109	,,	Skye, Duntuilm ..	6·32	105
,,	Blackpool	3·62	104	*R. & C.*	Tain, Tarlogie House ..	1·58	53
Yorks.	Wakefield, Clarence Pk.	3·69	174	,,	Ullapool	4·15	80
,,	Hull, Pearson Park ..	3·87	177	,,	Applecross Gardens ..	6·29	97
,,	Felixkirk, Mt. St. John	3·40	149	,,	Achnashellach	8·07	93
,,	York Museum ..	3·25	156	,,	Stornoway Airfield ..	5·77	104
,,	Scarborough	3·39	137	*Suth.*	Loch More, Achfary ..	6·68	78
,,	Middlesbrough.. ..	2·82	133	*Caith.*	Wick Airfield	2·84	90
,,	Baldersdale, Hury Res.	4·80	130	*Shet.*	Lerwick Observatory ..	6·67	157
Nor'ld	Newcastle, Leazes Pk.	3·12	133	*Ferm.*	Crom Castle	3·92	113
,,	Bellingham, High Green	4·35	127	*Armagh*	Armagh Observatory ..	2·42	85
,,	Lilburn, Tower Gdns. ..	3·10	93	*Down*	Seaforde	2·75	73
Cumb.	Geltsdale	4·75	145	*Antrim*	Aldergrove Airfield ..	2·41	74
,,	Keswick, High Hill ..	10·10	178	,,	Ballymena, Harryville	4·33	107
,,	Ravenglass, The Grove	4·83	108	*Lon.*	Garvagh, Moneydig ..	4·70	120
Mon.	Abergavenny, Larchfield	5·23	137	,,	Londonderry, Creggan	5·38	131
Glam.	Ystalyfera, Wern House	7·89	120	*Tyrone*	Omagh, Edenfel ..	5·06	133

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, JULY 1949

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1019·8	+3·9	85	50	75·6	57·4	66·5	+3·5	58·9	63	4·8	1·12	−1·05	7	8·1	50
Gibraltar	1016·4	−0·4	91	63	84·0	69·1	76·5	+1·7	69·9	70	2·3	0·00	—	0	11·3	79
Malta	1015·8	+1·1	93	65	85·5	70·0	77·7	−0·6	71·9	62	1·4	0·01	—	1	12·4	87
St. Helena	1019·1	−1·0	70	54	64·5	55·0	59·7	+1·4	55·2	94	6·8	2·34	−1·79	13	—	—
Lungi, Sierra Leone	1013·7	—	87	69	83·1	72·7	77·9	—	74·2	92	6·7	35·68	—	29	3·5	27
Lagos, Nigeria ..	1013·8	+0·7	88	67	82·6	70·6	76·6	−1·4	74·9	89	7·5	7·67	—	21	2·5	20
Kaduna, Nigeria ..	1011·8	—	87	64	82·5	67·3	74·9	+0·7	70·0	82	7·2	5·73	−4·89	12	6·3	50
Chileka, Nyasaland	1022·5	−0·7	82	51	75·4	56·1	65·7	+0·6	57·3	69	3·5	0·02	−0·11	1	7·1	63
Lusaka, Rhodesia ..	1020·2	−0·3	83	44	77·0	50·5	63·7	+2·2	53·3	67	0·8	0·00	−0·01	0	9·8	87
Salisbury, Rhodesia	1023·0	−0·6	76	37	70·5	44·9	57·7	+1·0	48·5	63	1·7	0·12	+0·09	1	8·1	72
Cape Town	1021·1	−0·2	80	39	65·2	44·8	55·0	+0·3	45·5	74	4·0	3·88	+0·26	18	—	—
Palmietfontein, S. Africa	1026·7	—	71	20	64·5	31·3	47·9	—	35·5	67	1·0	0·01	—	1	9·8	—
Mauritius	1020·4	−0·1	79	53	75·4	62·2	68·8	+0·5	62·8	71	3·7	1·24	−1·04	20	8·5	77
Calcutta, Alipore Obys.	1000·0	+1·1	94	76	89·9	79·5	84·7	+1·0	80·4	85	6·5	14·31	+1·61	23	4·0	30
Bombay	1003·3	−0·6	90	74	86·6	78·0	82·3	+0·9	78·4	86	6·4	23·64	−0·63	30	2·6	20
Madras	1004·6	+0·1	96	73	93·0	77·5	85·3	−2·3	76·1	75	6·7	2·99	−0·85	15	5·8	45
Colombo, Ceylon ..	1009·0	−0·1	86	71	85·2	75·8	80·5	−0·7	77·1	87	6·6	6·53	+2·10	25	5·6	45
Singapore	1009·4	+0·5	90	73	87·1	76·3	81·7	+0·4	76·6	80	5·3	7·40	+0·61	14	6·6	54
Hongkong	1006·6	+1·9	92	74	88·5	78·9	83·7	+1·2	78·2	81	—	6·71	−7·71	16	7·9	59
Sydney, N.S.W. ..	1018·8	+0·5	75	41	63·3	46·0	54·7	+2·0	47·2	75	3·8	2·30	−2·50	8	6·5	64
Melbourne	1017·3	−1·6	62	35	56·4	43·2	49·8	+1·1	45·3	79	5·5	2·22	+0·36	14	3·7	38
Adelaide	1019·1	−1·1	72	39	59·4	45·4	52·4	+0·5	47·4	73	5·0	2·25	−0·39	16	3·7	37
Perth, W. Australia	1017·2	−1·8	74	45	65·7	51·8	58·7	+3·5	53·5	78	5·5	6·56	0·00	23	4·0	39
Coolgardie	1018·8	−1·1	81	35	64·8	44·7	54·7	+3·5	48·9	70	4·0	1·95	+1·08	10	—	—
Brisbane	1019·9	+1·5	74	39	68·3	47·4	57·9	−0·6	51·8	63	2·7	0·82	−1·38	8	7·8	74
Hobart, Tasmania	1012·7	−1·0	62	34	54·8	41·1	47·9	+2·2	42·1	73	5·8	3·25	+1·07	14	4·4	47
Wellington, N.Z. ..	1012·8	−1·9	60	36	54·2	44·5	49·3	+2·9	47·3	85	5·9	5·61	−0·02	16	3·5	37
Suva, Fiji	1014·8	+0·8	86	64	78·2	69·5	73·9	+0·5	70·0	80	6·0	6·54	+1·61	25	4·3	39
Apia, Samoa ..	1012·0	+0·3	89	66	84·8	71·9	78·3	+0·1	74·1	80	4·2	7·05	+3·58	18	8·5	75
Kingston, Jamaica	1014·5	−0·2	93	71	90·1	74·5	82·3	+0·6	72·9	79	4·0	2·87	+1·25	8	7·4	57
Grenada, W. Indies	—	—	90	71	85·0	74·0	79·5	+0·3	75·0	78	4·0	6·51	−2·92	26	—	—
Toronto	1015·9	−1·5	93	53	83·0	64·9	73·9	+4·8	63·5	73	4·7	3·14	+0·30	8	8·9	59
Winnipeg	1012·5	+0·2	95	44	79·3	56·3	67·8	+1·4	57·1	82	5·4	2·29	−0·81	12	8·9	56
St. John, N.B. ..	1014·1	+0·5	83	49	72·9	56·0	64·5	+4·1	54·9	61	6·8	1·09	−2·54	9	7·7	50
Victoria, B.C. ..	1017·4	+0·1	80	44	69·6	51·0	60·3	+0·2	51·0	87	4·9	1·12	+0·70	8	10·5	67

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TEMPERATURE RISE ON CLEAR MORNINGS

By G. J. JEFFERSON, M.Sc.

Summary.—Gold's method for estimating maximum temperatures has been extended empirically to draw a forecast curve of the rise of temperature to the maximum on clear days. To do this, four points are fixed which correspond to the provision of four given amounts of energy by insolation to the lowest layers of air. Monthly average values are evaluated of the times taken from sunrise for these given amounts of energy to be absorbed. These figures, which show a low probable error, are used to make actual forecasts.

Introduction.—It has been shown by Gold* that the maximum day temperature at screen level may be estimated on occasions of unobstructed solar radiation by drawing a dry-adiabatic line on the tephigram in such a position that the area between the line and the early morning ascent curve represents a certain amount of energy dependent on the season of the year. Gold arrives at his figures by theoretical arguments which admittedly are not rigorous ; the energy absorbed by the ground itself is ignored, and the departure of the ascent curve at the time of maximum temperature from the dry adiabatic is often quite pronounced. Nevertheless, the argument leads to results which are useful in practical forecasting and are therefore justified empirically whatever the theoretical shortcomings may be.

There are therefore good grounds for extending the work empirically with the hopes of arriving at a forecast curve of the diurnal rise of temperature with time after sunrise.

Diurnal temperature curves.—In the practical drawing of such a curve we can plot two points. The first of these is the sunrise temperature (actual or forecast according to when the forecast is being made). Then using the latest upper air information and the monthly figures given by Gold we are able, with suitable adaptation of the lowest part of the temperature-pressure curve on the tephigram, to plot the maximum temperature to be reached.

It now remains to draw the correct curve of the rise of temperature with time between sunrise and the time of maximum temperature. The approximate

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*GOLD, E.; Maximum day temperatures and the tephigram. *Prof. Notes met. Off., London*, 5, No. 63, 1933.

shape of this curve is shown in Fig. 1. It has a sharp rise of temperature from the minimum value just after sunrise, after which the curve flattens and reaches a maximum about 2¼ hours after noon and then falls towards sunset.

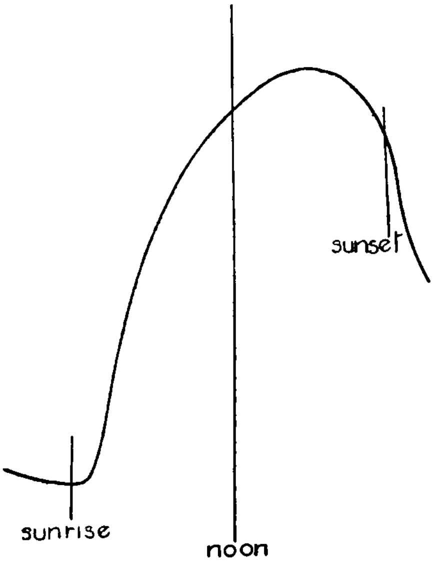

FIG. 1

To fill in this part of the curve more accurately than can be done by simple interpolation an attempt has been made in this paper to fix some points on this part of the curve for each occasion.

It has been found convenient in this paper to confine attention to one station, Northolt, to eliminate as far as possible variations of diurnal temperature range due to different surface and soil characteristics. The normal ascent curve at sunrise after a clear radiation night shows an inversion in the lowest layers. In Fig. 2 the ascent at sunrise is shown by an inversion ACB. If an isothermal

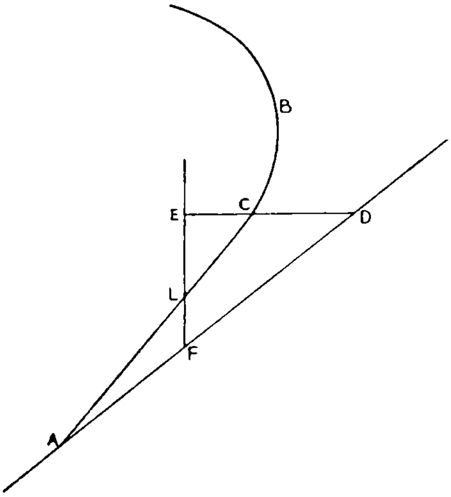

FIG. 2

FE is drawn so that the area ELC is equal to area ALF where area FED represents the amount of energy to be added up to the time of maximum temperature then DCB will represent the temperature-height curve at the time of maximum temperature. The actual rise of surface air temperature will be from A to D. Since the rise FD is fixed for any position on the line EF the actual rise from A to D will vary with the shape and slope of the line ACB. Thus a very steep inversion will produce a relatively large rise and a slight inversion or lapse will produce a smaller one. Thus the shape of the forecast curve to be drawn will depend directly on the profile of the ascent curve at sunrise and during the period of heating. The screen temperature reached at any given time after sunrise depends on the ascent curve. The amount of energy added to the lowest layers of air in the same time after sunrise is, however, independent of the ascent curve, and it is assumed that it will vary only with the season of the year as with Gold's figures for maximum temperature.

Monthly values of time taken to add given amounts of energy.—A period of 2 years was selected for which Northolt hourly observations were readily available—January 1945 to December 1946.

Days which fulfilled the following conditions were selected :—

(1) Low cloud amount less than 7 tenths between sunrise and noon or only increases above this value for one hourly observation.

(2) No medium or high cloud or not more than 3 tenths for more than one hour.

(3) No rain reported during the previous 12 hours.

(4) Visibility not falling below 1,000 yd. for more than 3 hours and no thick fog at any time.

Although it would be ideal to use only completely fine days, such days were not sufficiently numerous to allow satisfactory computations to be made in the period chosen. Conditions (1) and (2) ensure that interference with solar radiation by cloud is kept at a minimum and that the days selected are mainly clear of cloud or of the type with only broken cumulus. Condition (3) eliminates days on which the diurnal range of surface temperature is badly affected by wet ground, as would be the case on a clear morning in a ridge of high pressure immediately behind a cold front which has passed during the latter part of the night. It was not possible to take greater account of the effect of surface moisture in using heat for evaporation. This does appear to affect the results in the case of one month, June, as shown later. Condition (4) is mainly designed to eliminate days on which solar radiation is reduced over a period of some hours by thick fog. Attempt has been made as far as possible to eliminate days of this type but to include days which would otherwise be suitable but which have a certain amount of early morning ground fog only. An important aid in deciding which days to include here has been whether the sky has been reported visible or obscured during the period.

An examination of the upper air data available for the morning of each occasion was next made. Since there is no upper temperature sounding in the immediate vicinity of Northolt, the choice of suitable days usually lay between Larkhill and Downham Market. The wind was first examined from the surface up to 900 mb. The prevailing direction shown was usually sufficient for a choice to be made between the two as a basis for drawing on the tephigram an estimated ascent over Northolt. With some wind directions such as 220–270° and 360–40° this presented little difficulty but with others considerably more care was necessary. With winds between W. and N. fine mornings fulfilling the above requirements were of frequent occurrence, and a comparison of both Larkhill and Downham Market temperatures up to 900 mb. was necessary with occasional reference to Liverpool. It was necessary to reject some otherwise suitable days when temperatures showed considerable differences between the two.

Similar difficulties arose frequently on days with E.–SE. winds. Neither Larkhill nor Downham Market could be taken as representative of Northolt as the air at all three places had recently come over sea tracks differing both in length and temperature. On this account many days with winds from this direction had to be rejected.

The data used were basically the 0600 G.M.T. ascents, but reference to 1200 G.M.T. ascents occasionally showed considerable temperature changes above the level affected by surface heating, and a few days were rejected on this account also.

Nevertheless 59 days were found in the 2-year period which fulfilled all requirements.

The appropriate ascent for 0600 G.M.T. was first plotted on the tephigram up to 900 mb., and the lowest hourly temperature for Northolt was also plotted as an additional surface reading, no account being taken of the 300-ft. difference in level between Larkhill and Northolt. This implies in effect that air which had been over Larkhill has descended 10 mb. or so on reaching Northolt. While being only an approximation to the truth it will have little effect on the tephigram areas to be measured in the next stage. Downham Market and Northolt are almost at the same height so the problem does not arise in this case.

Assuming air above the lowest layers at Northolt is represented by the chosen ascent it is now possible to draw an estimated curve for Northolt which would represent the actual conditions at sunrise with reasonable accuracy.

Using this estimated ascent, the next step was to find for each day the temperature which would be reached when the energies corresponding to 0·25, 0·5, 1 and 2 cm.^{2} on the tephigram* have been supplied to the lowest layers.

Hourly temperature observations for each day show the time at which these temperatures were actually attained. These times were expressed in hours from sunrise. The temperature observations used were taken to the nearest degree and interpolations between hourly readings were made as required to the first decimal place of an hour. The times so derived were meaned for each month and are shown in Table I.

Discussion of results.—To obtain some idea of the value of these monthly average times for forecasting, the probable errors of the observed times in hours were evaluated. These are also shown in Table I. In order to obtain a sufficient number of observations for the evaluations, several of the months have been grouped together before computing the values of 0·6745 root mean square of the time measured minus the time forecast. The values so derived indicate the anticipated accuracy of the forecast. They show that in most cases there is at least an even chance of the time forecast being within approximately half-an-hour of the actual time, and in no case is the probable error greater than about 35–40 min.

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*London, Meteorological Office. Tephigram Form 2810. Energy constant: $2·78 \times 10^6$ ergs/cm.^{2}

TABLE I

Energy equivalent		Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
cm.²	No. of days	6	8	12	1	4	4	3	1	5	3	3	4
0·25	Average (hr.)	2·2	2·17	1·86	1·5	1·77	1·4	1·3	2·0	1·9	3·0	3·1	2·75
	Probable error	0·33		0·25	..	0·28			..	0·18			
	No. of days	6	8	13	1	4	4	3	1	5	3	3	4
0·5	Average (hr.)	3·2	2·8	2·2	2·0	2·4	2·07	1·9	2·6	2·4	4·1	4·0	4·6
	Probable error	0·49		0·3	..	0·28			..	0·58			
	No. of days	6	8	13	..	4	4	3	1	5	1	2	2
1	Average (hr.)	4·3	3·45	2·9	..	3·07	2·77	2·86	3·8	3·3	3·7	4·6	4·7
	Probable error	0·44		0·12	..	0·33			..	0·42			
	No. of days	3	8	12	..	4	3	3	1	5	..	..	..
2	Average (hr.)	5·8	4·4	3·6	..	3·97	3·9	3·6	6·8	4·4	..	..	..
	Probable error	0·61		0·57	..	0·34			..	0·48			

In Fig. 3 the monthly values are plotted with time in hours from sunrise against time of year. Smoothed curves drawn through the points show the general form of a sine curve with a minimum value in June and a maximum in December as would be expected from the annual solar cycle and the variation of strength of insolation. In the case of energy corresponding to 2 cm.² the curve runs off to infinite values during the months of November, December and January as the required temperature is never reached. This is borne out by Gold's monthly figures for the area up to the time of maximum temperature which are less than 2 cm.² for these three months.

Individual monthly values are of interest. In particular the month of June shows a higher value than would be expected from the general run of the curves. Although only four occasions were found in June during the 2 years closer agreement would have been expected. June 1946 was described in the *Monthly Supplement to the Daily Weather Report* as " Dull, wet and cool . . . Although no unusually heavy daily amounts were registered there was an excessive number of days with rain . . . Rain was above normal in most places ". June 1945 was described as " Mainly unsettled . . . Rather cool weather prevailed, mainly of a showery type ". It thus seems possible that the ground characteristics at Northolt were affected by the ground being abnormally wet for the time of the year.

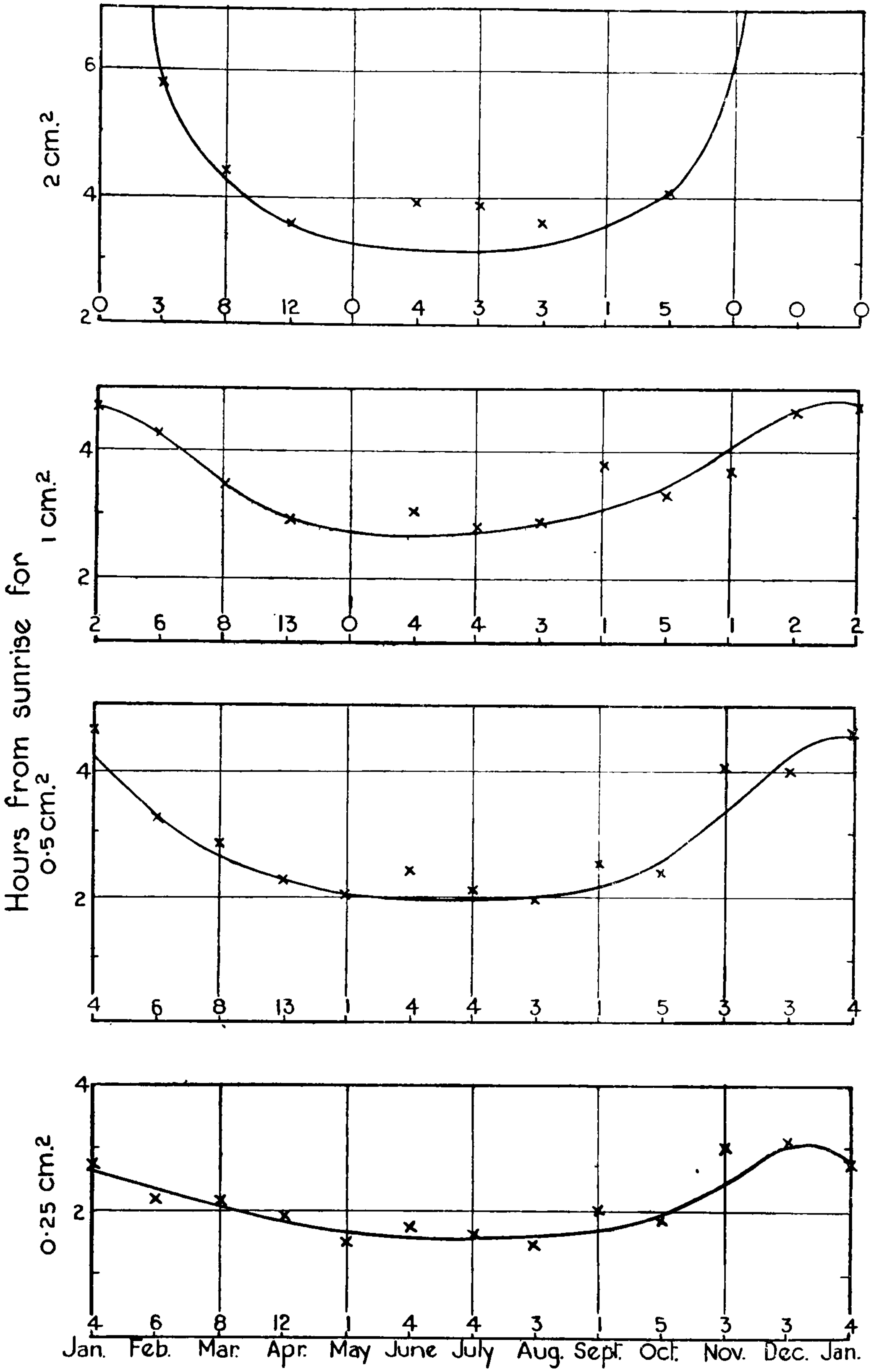

FIG. 3—CURVES SHOWING MONTHLY AVERAGES OF ENERGY PUT INTO THE LOWEST LAYERS OF AIR AT NORTHOLT BY SOLAR RADIATION

Number of occasions found in each month are shown at the base of the ordinate in each case

In drawing the curves more weight has been given to points which represent the largest number of days consistent with the general run of the curve. The points fit least well in the case of energy corresponding to 2 cm.^{2}. This can be expected since the diurnal curve has begun to flatten off by the time this amount of energy has been added, and variations in time at which any given temperature will be reached are magnified as compared with the earlier part of the heating period. For actual use corrected monthly mean values have been obtained from the smoothed curves. These are tabulated in Table II.

TABLE II

Energy equivalent	Average time from sunrise											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
cm.^{2}	*hours*											
0·25	2·6	2·3	2·0	1·8	1·6	1·5	1·4	1·5	1·6	1·9	2·4	3·0
0·5	4·2	3·3	2·7	2·3	2·1	1·95	1·9	1·95	2·1	2·6	3·3	4·2
1	4·7	4·2	3·5	3·0	2·8	2·7	2·75	2·9	3·1	3·5	4·1	4·7
2	..	5·8	4·5	3·7	3·3	3·1	3·2	3·4	3·6	4·0	..	..

Practical examples.—In practice, the evaluation of temperatures which will be reached by adding the given amounts of energy demands some simple graphical method for the measurement of areas on the tephigram. A simple scale was scribed on a perspex sheet as shown in Fig. 4, in which the areas ABJ, ACH, ADG, and AEF are 0·25, 0·5, 1 and 2 cm.^{2} respectively. With this it is a simple matter to estimate the required temperatures: the line AE being laid along the surface pressure line the position of the scale is then adjusted until the correct position is found for the isothermal line AF for each standard area which is shown by the line EF in Fig. 4.

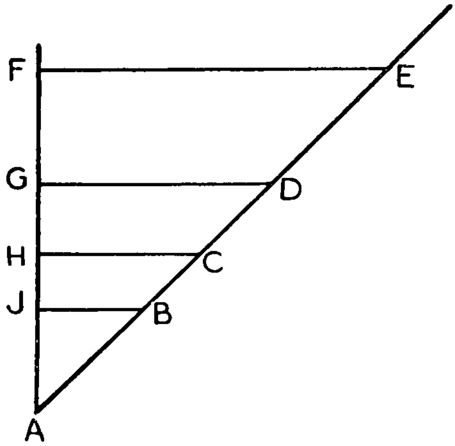

FIG. 4

The use of the monthly figures in drawing the forecast screen temperature curve is shown in Fig. 5 for four actual examples at different times of the year. All the days selected were characterised by clear or almost clear skies ; while one, December 12, 1946, had some shallow fog, the others had mainly good visibility throughout. There were no changes of air mass on any of the days.

The appropriate ascent for 0600 G.M.T. has been plotted for the four days in Fig. 5. The Northolt hourly minimum temperature has been added as an additional point T and the estimated curve for Northolt drawn in the same way as described on p. 36. The points A, B, C, D in each figure correspond to the temperatures to be reached when the four standard amounts of energy have been added to the lowest layers.

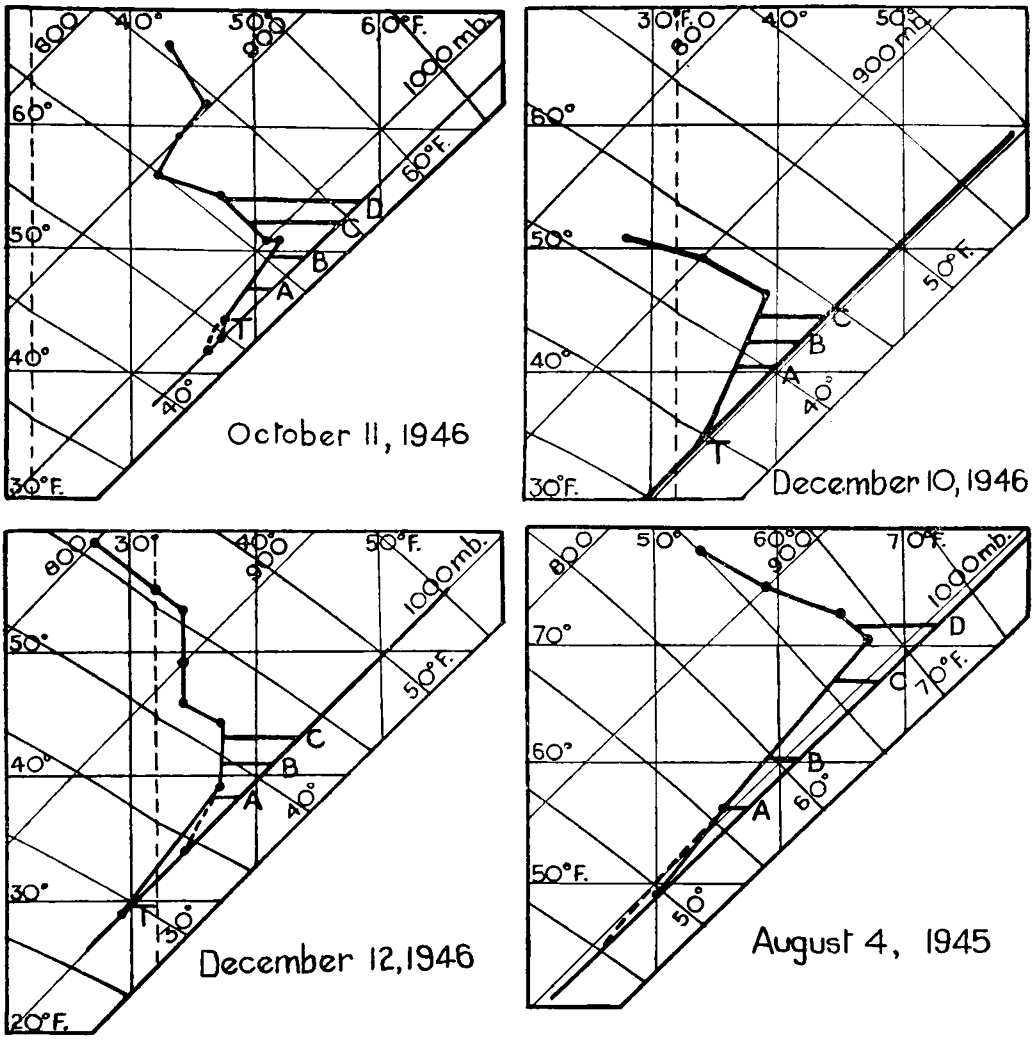

FIG. 5—FORECASTING TEMPERATURES ON A TEPHIGRAM BY THE USE OF "ENERGY EQUIVALENTS"

The pecked portion of the curve refers to the original upper air ascent before the Northolt minimum hourly temperature is applied

The forecast curves are drawn in Fig. 6 for each of the days with the aid of points L, M, N, P. These correspond with the temperatures of the points A, B, C, D read from Fig. 5, the time being fixed in hours from sunrise taken from Table II.

In each case the curves of the actual temperatures correspond reasonably well with the forecast curves. On October 11, 1946, it is noticeable how the actual curve falls furthest below the forecast curve at 0800 when there was 7–8 tenths of low cloud.

The maximum recorded on August 4, 1945, was 3 degrees above the estimated figure.

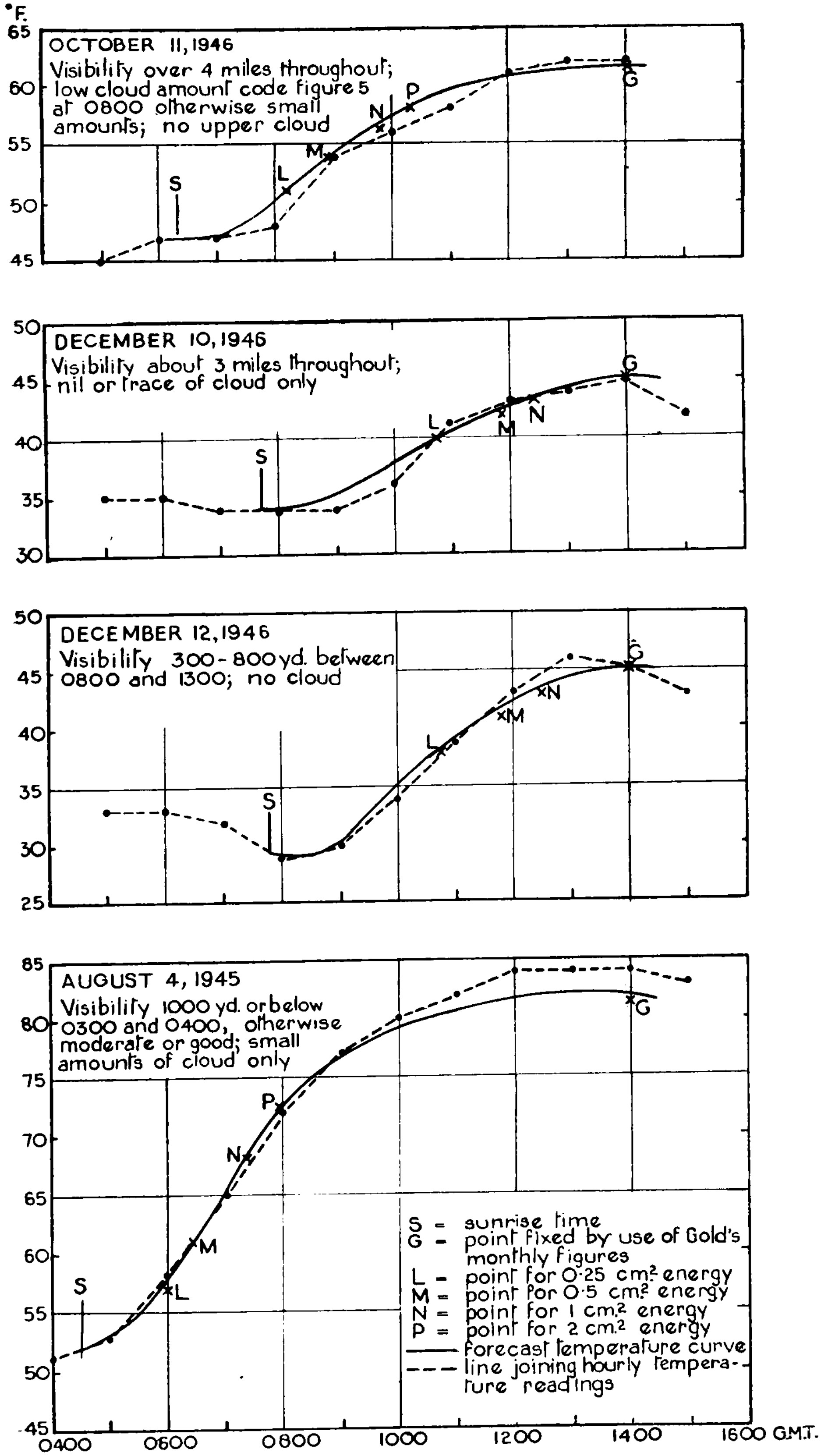

FIG. 6—COMPARISON OF FORECAST TEMPERATURES WITH HOURLY TEMPERATURE READINGS AT NORTHOLT

FREQUENCY OF RADIATION AND WIND FROSTS DURING SPRING IN KENT

By W. H. HOGG, M.Sc.

The distinction between a radiation frost and a wind frost is familiar to most fruit-growers. It is possible to provide some protection against radiation frosts but not against wind frosts, apart from the use of shelter to reduce convective heat loss from the buds or blossom.

A large capital outlay may be necessary to provide protection against frost, and therefore it is important to know what proportion of frosts occur with wind. In an attempt to provide this information the data from all available stations in Kent have been examined for the 30-year period 1919–48.

Definitions.—Although it is usually possible to distinguish the two types of frost, precise definitions have not so far been proposed. A screen frost is defined as a temperature of 32°F. or less ; in practice a temperature of 32·4°F. is generally used, as standard minimum thermometers are read to whole degrees. Recent work suggests that apple buds are damaged when the temperature falls below about 28°F., but the relation between screen temperature and bud temperature has not yet been investigated, and a screen minimum of 30°F. has been suggested by the East Malling Research Station as a convenient definition of frost for fruit-growers. To satisfy both meteorologists and agriculturists, and to allow for possible modifications of the definition, frequencies are given in 2-degree steps from 32° to 20°F.

For the definition of wind frost, East Malling Research Station has suggested that the term should be used when the wind speed exceeds 5 m.p.h. at a height of 30 ft. This is the equivalent wind speed for Beaufort force 2 which has therefore been adopted, as few stations are equipped with anemometers. The limits of speed at 30 ft. corresponding with Beaufort forces 2 and 3 are 4–7 m.p.h. and 8–12 m.p.h. respectively ; the frequencies are therefore based on a limiting wind speed of 7·5 m.p.h. instead of 5 m.p.h., but this is probably no disadvantage.

Effect of time of observations.—The definitions given above should refer to the minimum temperature and to the wind speed at the same time. At most climatological stations the only observations available are the minimum temperature and the wind speed at 0700 or 0900 G.M.T.* It is therefore necessary to allow for the following effects:—

(*a*) the increase in wind speed from the probable time of minimum temperature to the 0700 or 0900 observation. Unless some adjustment is made for this, the frequencies of wind frost will be over-estimated and those of radiation frost correspondingly under-estimated.

(*b*) the apparent difference in the frequency of frost days with different times of observation. When observations are made at 0700 a single frost is more likely to give rise to two frost days than when observations are made at 0900.

Observed frequencies have been adjusted for the diurnal variation of wind speed by factors based on mean hourly temperatures and wind speeds at Kew Observatory. The lowest mean hourly temperatures occur at about 0600 in March, 0500 in April and 0400 in May. Mean hourly wind speeds for

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*All times are G.M.T.

1928–37 are given in Table I. The values refer only to those days when the mean hourly speed fell below 7·5 m.p.h. during hours centred on 0430, 0530 or 0630.

TABLE I—MEAN HOURLY WIND SPEED AT KEW ON MORNINGS WITH LIGHT BREEZE

Period: 1928–37

	0400	0500	0600	0700	0800	0900
			miles per hour			
March	..	3·6	3·7	4·1	4·8	6·1
April	..	4·0	4·3	5·1	6·3	7·5
May	3·7	3·7	4·3	5·2	6·3	7·1

In March, the wind speed can be expected to increase by 0·4 m.p.h. between 0600 and 0700, and a few radiation frosts may therefore be classified as wind frosts. The range of Beaufort force 3 is 7·5 to 12·5 m.p.h., and, assuming that the winds are distributed evenly throughout this range, 4/50 of the frosts which occur with a force-3 wind at 0700 have been included with the radiation frosts. For observations at 0900 the mean increase in wind speed since 0600 is 2·4 m.p.h. and 24/50 of the force-3 wind frosts have therefore been transferred to the radiation frosts. Similarly, the following factors have been adopted for other months : April 0700, 11/50; April 0900, 35/50; May 0700, 15/50; May 0900, 34/50.

The effect of time of observation on the recorded frequency of frost days has been investigated by Brooks*. The data in Table II have been taken from his table of 10-year frequencies of frost at Kew with different hours of setting and reading.

TABLE II—FROST FREQUENCIES AT KEW, 1928–37

Period	March	April	May
		number of occasions	
0700–0700	85	11	2
0900–0900	65	9	2
1800–0700	59	9	2
2100–0900	59	9	2

The last two lines give the frequency of night frost, which is the same whether observed between 1800 and 0700 or 2100 and 0900. This is probably the frequency in which the fruit-grower is most interested, for it is very unlikely that a frost during the day will not also be recorded in either the preceding or the following night. Also the use of night frosts avoids the risk of counting the same frost on two days, which occurs when the temperature is 32°F. or less at the morning observation. The first two lines show that this happens in March 6 times in 10 years with observations at 0900 only, and 26 times with observations taken at 0700; it is, of course, possible that on a few occasions the frost occurred during the day and not in the night. Thus no great error is introduced by combining or comparing frequencies of night frosts with those of 24-hr. frosts measured at 0900.

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*BROOKS, C. E. P.; The effect of the hours of setting and reading the mininum thermometer on the number of screen frosts. Typescript, Meteorological Office, London, 1944.

Times of observation are included in Table III and these show that the frost frequencies refer mainly to night frosts or to frosts during the 24 hr. ending at 0900. No adjustments have been made in the frequencies, except for a few places where observations were taken only at 0700 for part of the period; these observations have been individually examined and the frequencies adjusted to allow for the occasions when it was likely that a single frost was responsible for the entries on two days.

Effect of period of observation.—The 30-year period 1919–48 has been used as the standard for these frequencies. For each month from March 1917 onwards rough estimates have been made of the amount by which the general temperature over the whole county differs from the mean for the period 1881–1915. From these, it can be estimated whether the data given in Tables IV–VI are likely to over-estimate or under-estimate the total frost frequencies over the standard period. Table III gives the probable effect of the period on the frequencies.

TABLE III—EFFECT OF PERIOD ON FROST FREQUENCIES

Station	Period	Time of observation	March	April	May
Biggin Hill	1921–40	1800, 0700	o	+	o
Manston	1929–48	1800, 0700†	+	o	+
Lympne	1921–48	1800, 0700†	o	o	o
Bromley	1927–48	0900	o	o	o
Canterbury	1931–44	0900	+	o	+
Tunbridge Wells	1919–48	0900†	o	o	o
Goudhurst	1935–48	0900†	+	–	+
East Malling	1925–48	0900	o	o	o
Wye	1925–48*	0900	o	o	o
Margate	1917–48*	0900†	o	o	o
Ramsgate	1916–48*	0900†	o	o	o
Deal	1922–48*	0900†	o	o	o
Dover	1912–48*	0900†	o	o	o
Folkestone	1914–48*	0900†	—	o	o
Dungeness	1918–48	1800, 0700†	o	o	o

+ Frequencies probably higher than for the standard period.
– Frequencies probably lower than for the standard period.
o Frequencies probably close to those for the standard period.
* Record incomplete.
† Times of observation have changed; the times given refer to most of the period.

Sites of stations.—The importance of local topography in relation to frost incidence is well known. A description of the surroundings of each station used is given below and each of the stations is allocated to one of four topographical types.

Hill-top sites.—Bromley, 213 ft. Just over the brow of a slope to the south-west which falls 40 ft. in 240 ft. Sheltered by buildings and best described as a sheltered hill-top site.

Biggin Hill, 567 ft. On top of a hill with a valley falling to about 400 ft. to the west and south-west. In other directions the ground is fairly level. The country generally is hilly and somewhat wooded.

Manston, 154 ft. A well exposed site near the centre of the Isle of Thanet.

Lympne, 346 ft. On top of the inner cliffs bordering Romney Marsh; to the south there is a steep drop of about 330 ft. beyond which the country is flat. About 2 miles from the sea.

Hill-side sites.—Canterbury, about 100 ft. In a residential area on the outskirts of Canterbury. On the lower slopes of the Great Stour Valley.

Tunbridge Wells, 351 ft. From 1919 to 1930 (approx.) a sheltered hill-top site. From about 1931 onwards the station has been in a sparsely built-up area; in a gully with the ground sloping moderately towards west-north-west.

Goudhurst, 390 ft. At the head of a valley, on a spur between two tributary valleys. In well-wooded country.

Plain sites.—East Malling, 132 ft. On the flank of a low escarpment. To the south the land rises some 130 ft. in $\frac{3}{4}$ mile; to the north-east it falls to the Medway, about 120 ft. in $1\frac{1}{2}$ miles. There is a railway embankment 12–14 ft. high about 40 yd. to the south.

Wye, 164 ft. At the base of hills on a very slight spur. The Downs to the east and west rise above 500 ft.

Coast sites.—The observations were taken near the coast at the following places:—

	ft.		ft.
Margate	51	Dover	19
Ramsgate	80	Folkestone.. ..	128
Deal	18	Dungeness.. ..	20

These sites can be considered well-exposed except at Deal, where the observations were taken at a rather sheltered site for many years. .

Estimated frequency of frost.—Tables IV–VI give the estimated frequencies of frost, radiation frost and wind frost, for minimum temperatures $\leqslant 32$°F. $\leqslant 30$°F. . . . . $\leqslant 20$°F.*. The observed frequencies have been adjusted in the manner described on p. 43. Also, the proportion of wind frosts to total frosts (expressed as a percentage) is given for minimum temperatures $\leqslant 32$°F. and $\leqslant 30$°F.

The effect of site is clear from Tables IV–VI, where only Bromley and Dungeness appear anomalous. No doubt Bromley is anomalous because the site is more sheltered than those at other hill-top stations, but it is not evident why there should be more frost at Dungeness than at other coast stations.

In March, frost is least likely along the coast, more likely on hill-tops, and most likely on the hill-slopes and in the plains. For radiation frosts only, the different sites show the same relative susceptibility as for total frosts. Only 25–30 per cent. of frosts are wind frosts on the hill-sides and in the plains, compared with about 50 per cent. on the hill-tops and rather less along the coasts. Wind frosts are on the whole rather more frequent on the hill-tops than on the hill-sides or on the plains ; they are least frequent along the coast.

In April, frost is least likely along the coasts but there is no marked difference between the other sites ; this is true also for radiation frosts. Wind frosts also are least likely along the coasts where they constitute 35 per cent. or more of all frosts at most places ; some 35–45 per cent. of frosts on the hill-tops are wind frosts, and 10–30 per cent. on the hill-sides and plains.

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* As minimum thermometers are read to whole degrees the exact temperature for which frequencies are given are $\leqslant 32.4$°F., $\leqslant 30.4$F., ... $\leqslant 20.4$°F.

In May the frequencies are low and little generalization is possible. Both radiation frosts and wind frosts are most frequent on hill-sides and plains.

Acknowledgements.—Acknowledgement is made to the staff of East Malling Research Station with whom this subject has been discussed, and in particular to Dr. W. S. Rogers of the Pomology Department; to the staff of the Agricultural Branch of the Meteorological Office who assisted with the computation and to the Climatological Branch of the Meteorological Office who made available the daily returns on which the investigation is based.

TABLE IV—MEAN FROST FREQUENCY IN MARCH

	Type of frost	⩽32°	⩽30°	⩽28°	⩽26°	⩽24°	⩽22°	⩽20°
HILL-TOP					*days*			
Biggin Hill	Radiation	4·5	2·9	1·6	0·9	0·8	0·5	0·1
	Wind	3·8	2·1	0·9	0·2	0·1	0·1	0
	Total	8·3	5·0	2·5	1·1	0·9	0·5	0·1
	Wind/total (%)	46	42	..	..	..	..	..
Manston	Radiation	3·2	1·5	0·8	0·3	0·1	0	0
	Wind	2·9	1·3	0·6	0·3	0·1	0	0
	Total	6·1	2·7	1·4	0·6	0·3	0	0
	Wind/total (%)	48	46	..	..	..	..	..
Lympne	Radiation	3·5	1·9	0·9	0·3	0·2	0·1	<0·1
	Wind	4·2	2·1	1·2	0·6	0·5	0·2	0·1
	Total	7·7	4·0	2·1	0·9	0·6	0·3	0·1
	Wind/total (%)	54	52	..	..	..	..	..
Bromley	Radiation	7·0	4·1	2·3	1·3	0·7	0·3	0·1
	Wind	1·9	1·1	0·5	0·3	0·1	<0·1	<0·1
	Total	8·9	5·2	2·8	1·6	0·8	0·3	0·1
	Wind/total (%)	21	22	..	..	..	..	..
HILL-SIDE								
Canterbury	Radiation	7·4	5·4	2·9	1·4	0·7	0·4	0·1
	Wind	2·4	1·4	0·7	0·2	0·2	0	0
	Total	9·8	6·8	3·6	1·6	0·9	0·4	0·1
	Wind/total (%)	25	21	..	..	..	.	..
Tunbridge Wells	Radiation	8·4	6·2	4·1	2·3	1·2	0·6	0·4
	Wind	3·0	1·9	1·1	0·6	0·3	0·2	0·1
	Total	11·4	8·0	5·1	2·9	1·5	0·8	0·5
	Wind/total (%)	26	23	..	..	..	..	..
Goudhurst	Radiation	9·3	6·3	4·1	2·1	0·9	0·4	0·2
	Wind	3·4	2·1	1·2	0·6	0·4	0·3	0·1
	Total	12·6	8·4	5·4	2·8	1·2	0·7	0·3
	Wind/total (%)	27	25	..	..	..	..	..
PLAIN								
East Malling	Radiation	8·4	5·7	3·5	2·0	1·0	0·6	0·2
	Wind	3·1	1·7	0·7	0·4	0·2	0·2	<0·1
	Total	11·5	7·3	4·3	2·4	1·2	0·8	0·3
	Wind/total (%)	27	23	..	..	..	..	..
Wye	Radiation	7·5	5·1	2·7	1·7	0·8	0·5	0·3
	Wind	3·0	1·4	0·8	0·3	0·2	0·1	0·1
	Total	10·5	6·5	3·5	2·0	1·0	0·5	0·3
	Wind/total (%)	28	21	..	..	..	..	..
COAST								
Margate	Radiation	1·5	0·6	0·2	0·1	<0·1	0	0
	Wind	1·1	0·5	0·1	0·1	<0·1	0	0
	Total	2·6	1·1	0·3	0·2	0·1	0	0
	Wind/total (%)	41	44	..	..	..	..	..

TABLE IV—MEAN FROST FREQUENCY IN MARCH—*continued*

	Type of frost	⩽32°	⩽30°	⩽28°	⩽26°	⩽24°	⩽22°	⩽20°
COAST—*contd.*					*days*			
Ramsgate	Radiation	2·1	0·8	0·3	0·1	<0·1	0	0
	Wind	1·4	0·6	0·2	0·1	0·1	<0·1	0
	Total	3·6	1·4	0·5	0·2	0·1	<0·1	0
	Wind/total (%)	40	45	..	..	..	..	..
Deal	Radiation	3·5	2·2	1·3	0·6	0·2	0·1	0·1
	Wind	1·9	1·1	0·4	0·1	0·1	<0·1	0
	Total	5·4	3·3	1·7	0·7	0·3	0·2	0·1
	Wind/total (%)	35	33	..	..	..	..	..
Dover	Radiation	2·0	1·2	0·6	0·2	0·2	0·1	<0·1
	Wind	2·0	1·0	0·3	0·2	0	0	0
	Total	4·0	2·2	0·8	0·4	0·2	0·1	<0·1
	Wind/total (%)	51	47	..	..	..	..	..
Folkestone	Radiation	2·1	0·9	0·3	0·2	0·1	<0·1	0
	Wind	2·3	1·2	0·5	0·2	0·1	0·1	0
	Total	4·4	2·0	0·9	0·4	0·3	0·1	0
	Wind/total (%)	53	57	..	..	..	..	..
Dungeness	Radiation	4·6	3·6	1·9	1·1	0·6	0·3	0·1
	Wind	2·3	1·3	0·6	0·4	0·1	0	0
	Total	6·9	4·9	2·5	1·5	0·7	0·3	0·1
	Wind/total (%)	33	27	..	..	..	..	..

Entries of <0·1 indicate frequencies >0 and <0·05.

Apparent discrepancies are due to the fact that the lines giving total frost frequency and wind/total (%) have been worked from the total frequencies and not from the mean frequencies of radiation and wind frost.

TABLE V—MEAN FROST FREQUENCY IN APRIL

	Type of frost	⩽32°	⩽30°	⩽28°	⩽26°	⩽24°
HILL-TOP				*days*		
Biggin Hill	Radiation	2·7	1·0	0·4	0·1	0
	Wind	1·3	0·4	0·1	0	0
	Total	4·0	1·4	0·5	0·1	0
	Wind/total (%)	34	29	..	..	..
Manston	Radiation	0·8	0·3	0	0	0
	Wind	0·5	0·1	0	0	0
	Total	1·3	0·5	0	0	0
	Wind/total (%)	37	29	..	..	..
Lympne	Radiation	1·2	0·7	0·3	0	0
	Wind	1·0	0·5	0·1	0	0
	Total	2·2	1·1	0·3	0	0
	Wind/total (%)	45	41	..	..	..
Bromley	Radiation	1·5	0·7	0·1	0	0
	Wind	0·8	0·3	0·1	<0·1	0
	Total	2·4	1·0	0·2	<0·1	0
	Wind/total (%)	35	32	..	..	..
HILL-SIDE						
Canterbury	Radiation	1·8	0·9	0·4	0·1	0
	Wind	0·2	0·1	0·1	0	0
	Total	2·0	1·1	0·4	0·1	0
	Wind/total (%)	11	13	..	..	..
Tunbridge Wells	Radiation	3·3	2·1	0·9	0·4	0·1
	Wind	1·2	0·7	0·2	0·2	<0·1
	Total	4·5	2·8	1·2	0·6	0·1
	Wind/total (%)	27	25	..	..	..

TABLE V—MEAN FROST FREQUENCY IN APRIL—*continued*

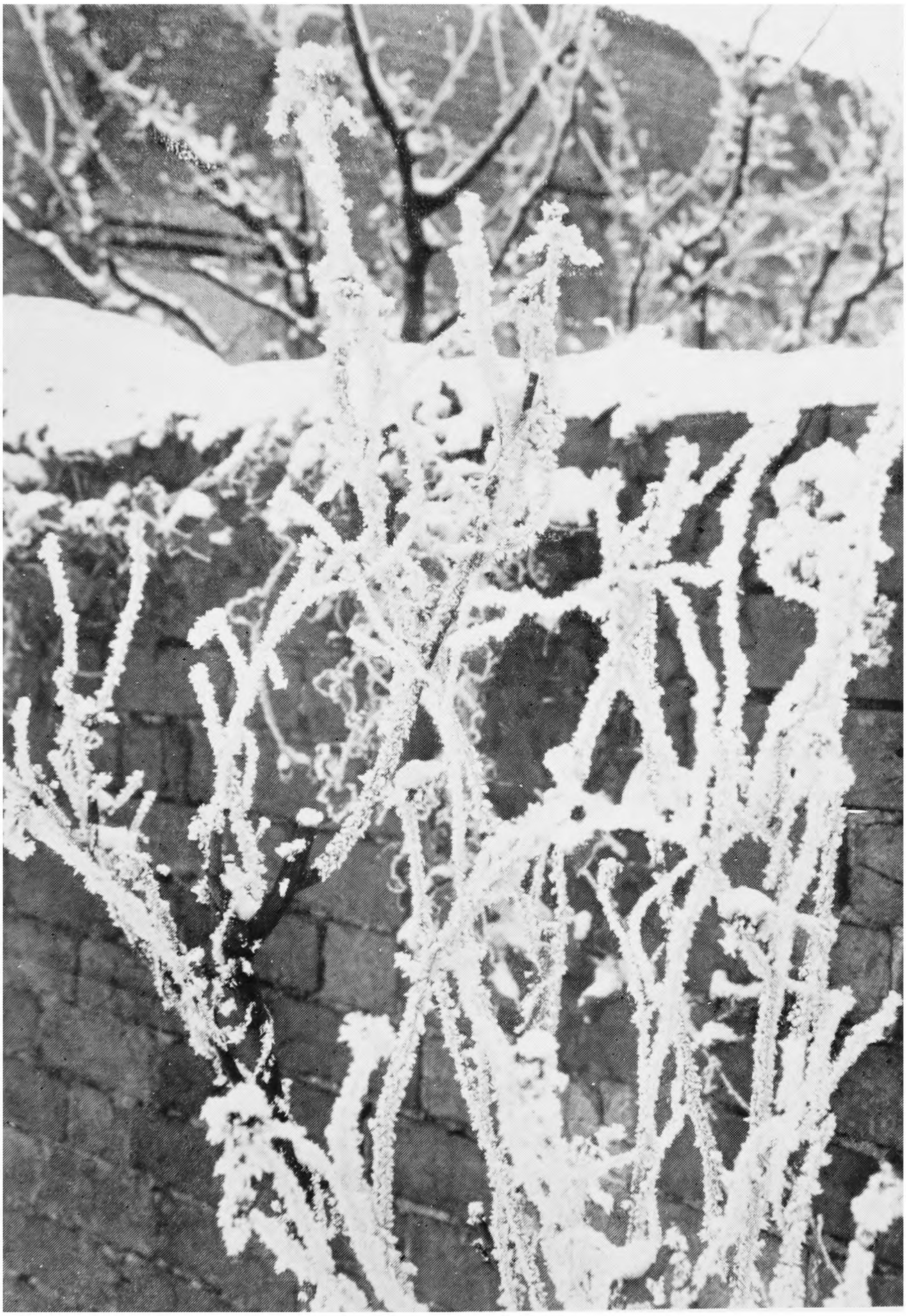
	Type of frost	≤32°	≤30°	≤28°	≤26°	≤24°
HILL-SIDE—*contd.*				*days*		
Goudhurst	Radiation	3·4	2·1	1·1	0·3	0·1
	Wind	1·4	0·9	0·4	0	0
	Total	4·9	3·1	1·5	0·3	0·1
	Wind/total (%)	29	30	..	..	..
PLAIN						
East Malling	Radiation	2·9	1·6	0·5	0·2	0
	Wind	1·1	0·6	0·2	0	0
	Total	4·0	2·2	0·7	0·2	0
	Wind/total (%)	28	26	..	..	..
Wye	Radiation	2·5	1·3	0·5	0·2	0
	Wind	0·5	0·2	0·1	0	0
	Total	3·1	1·5	0·6	0·2	0
	Wind/total (%)	18	14	..	..	..
COAST						
Margate	Radiation	0·1	<0·1	0	0	0
	Wind	0·2	0·1	0	0	0
	Total	0·3	0·1	0	0	0
	Wind/total (%)	60	75	..	..	..
Ramsgate	Radiation	0·3	0·1	0	0	0
	Wind	0·4	0·1	0·1	0	0
	Total	0·7	0·3	0·1	0	0
	Wind/total (%)	53	57	..	..	..
Deal	Radiation	0·4	0·2	0·1	0	0
	Wind	0·3	<0·1	0	0	0
	Total	0·7	0·3	0·1	0	0
	Wind/total (%)	39	14	..	..	..
Dover	Radiation	0·5	0·2	<0·1	0	0
	Wind	0·1	0	0	0	0
	Total	0·6	0·2	<0·1	0	0
	Wind/total (%)	19	0	..	..	..
Folkestone	Radiation	0·4	0·1	0	0	0
	Wind	0·2	0	0	0	0
	Total	0·6	0·1	0	0	0
	Wind/total (%)	36	0	..	..	..
Dungeness	Radiation	1·9	0·9	0·3	0·1	0
	Wind	0·5	0·3	0·1	0	0
	Total	2·4	1·1	0·4	0·1	0
	Wind/total (%)	22	24	..	..	..

Entries of <0·1 indicate frequencies >0 and <0·05.

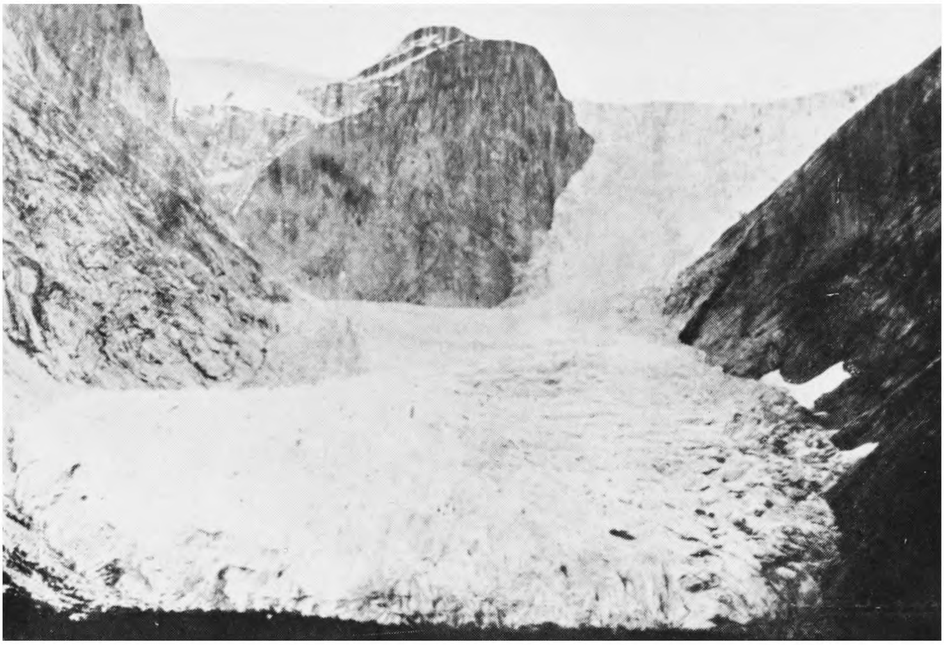
Apparent discrepancies are due to the fact that the lines giving total frost frequency and wind/total (%) have been worked from the total frequencies and not from the mean frequencies of radiation and wind frost.

TABLE VI—MEAN FROST FREQUENCY IN MAY

	Type of frost	≤32°	≤30°	≤28°	≤26°	≤24°
HILL-TOP				*days*		
Biggin Hill	Radiation	0·2	0·1	0	0	0
	Wind	0·1	0	0	0	0
	Total	0·3	0·1	0	0	0
	Wind/total (%)	43	0	..	..	..
Manston	Radiation	0·3	0	0	0	0
	Wind	0·1	0·1	0	0	0
	Total	0·4	0·1	0	0	0
	Wind/total (%)	33	100	..	..	..



RIME AT STONEHOUSE, GLOUCESTERSHIRE, JANUARY 26, 1945



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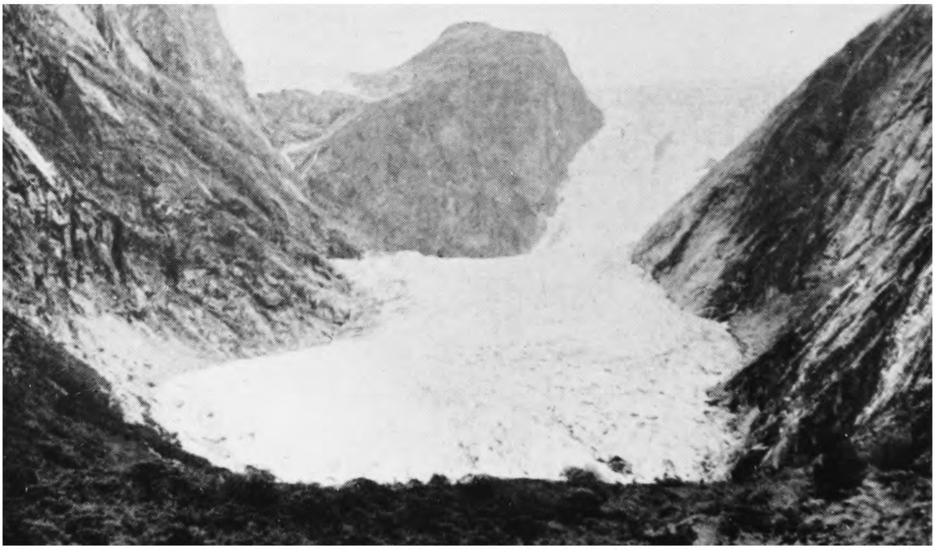
1869



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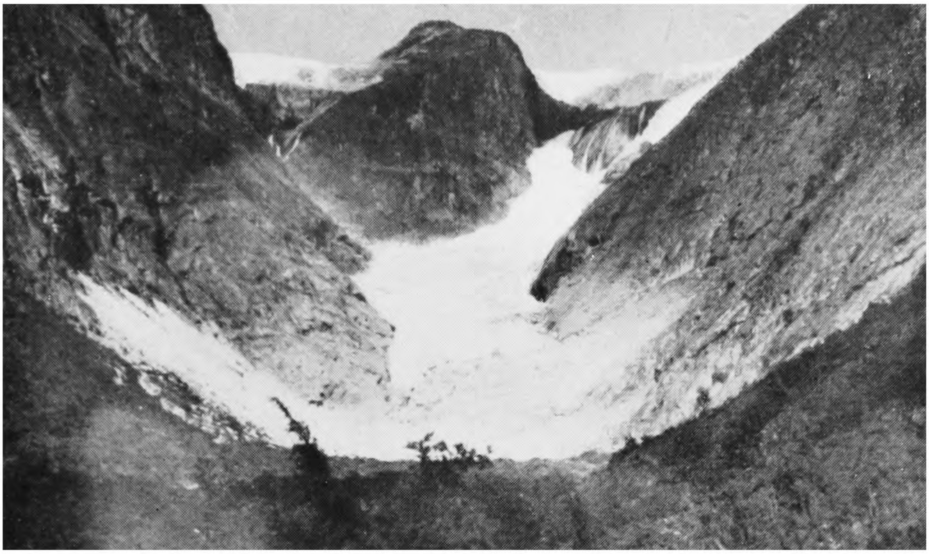
1933

ÅBREKKE GLACIER, JOTUNHEIM, SHOWING RECESSION

(see January 1950, p. 16)



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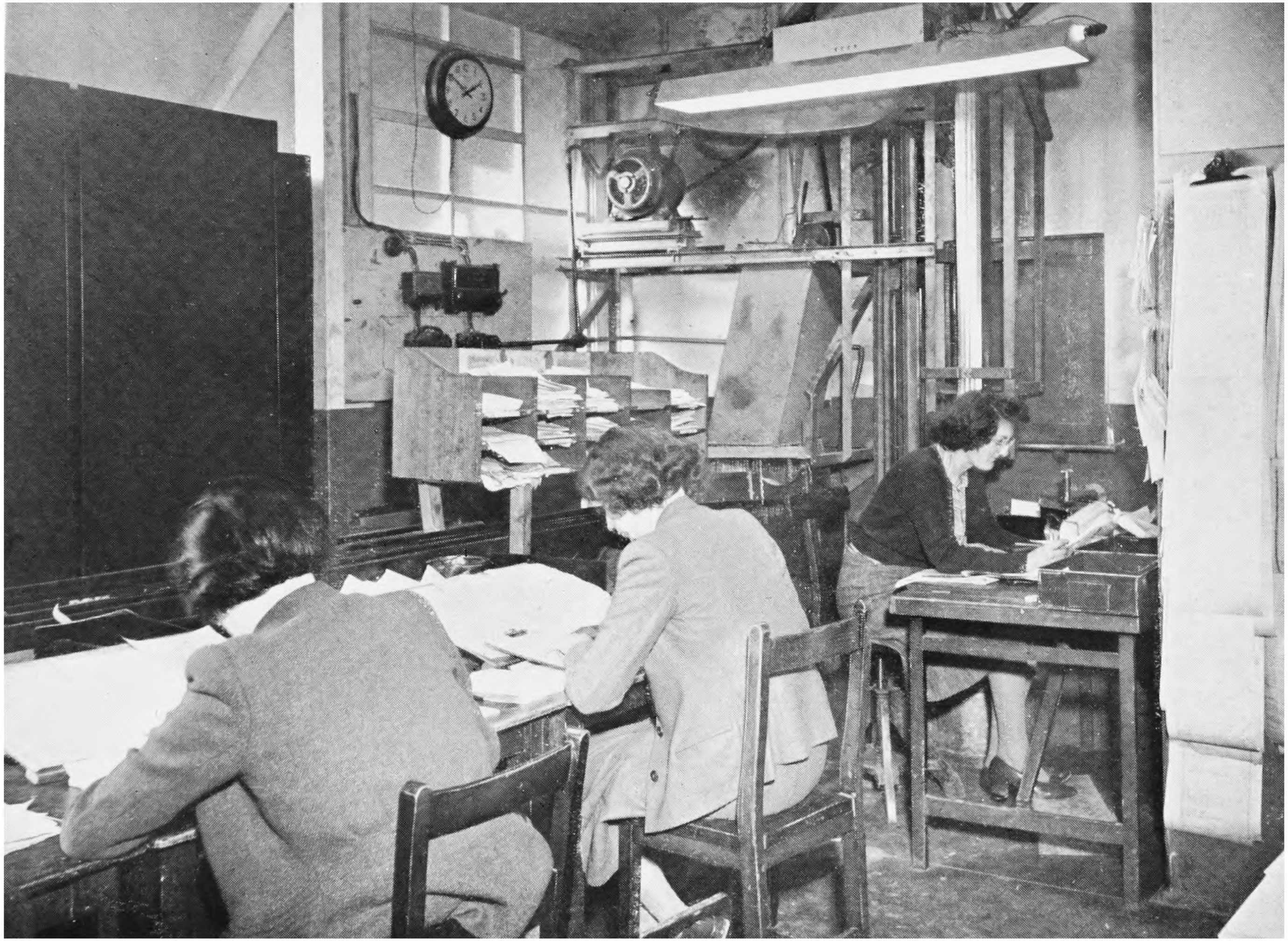
1946

ǺBREKKE GLACIER, JOTUNHEIM, SHOWING RECESSION
(see January 1950, p. 16)

PLOTTING A SYNOPTIC CHART AT THE CENTRAL FORECASTING OFFICE, DUNSTABLE, FOR USE ON THE AIRMET BROADCAST



CORNER OF THE COMMUNICATIONS ROOM AT CENTRAL FORECASTING OFFICE, DUNSTABLE

Messages are received from the W/T room by an overhead conveyor belt and from the teleprinter room by a conveyor belt in the channel on the left of the picture. The assistant in the background is the scrutineer who examines and distributes all incoming messages. The two assistants in the foreground are preparing reports for outward transmission.

TABLE VI—MEAN FROST FREQUENCY IN MAY—*continued*

	Type of frost	⩽32°	⩽30°	⩽28°	⩽26°	⩽24°
HILL-TOP—*contd.*						
Lympne	Radiation	0·5	0·2	<0·1	0	0
	Wind	0·1	0	0	0	0
	Total	0·6	0·2	<0·1	0	0
	Wind/total (%)	18	0	..	..	..
Bromley	Radiation	0·5	0·3	0·1	0	0
	Wind	0·1	0·1	0	0	0
	Total	0·6	0·4	0·1	0	0
	Wind/total (%)	21	33	..	..	..
HILL-SIDE						
Canterbury	Radiation	1·0	0·4	0·1	0	0
	Wind	0·1	0	0	0	0
	Total	1·1	0·4	0·1	0	0
	Wind/total (%)	7	0	..	..	..
Tunbridge Wells	Radiation	0·7	0·4	0·2	0·1	0
	Wind	0·3	0·2	0·2	<0·1	0
	Total	1·0	0·6	0·4	0·1	0
	Wind/total (%)	32	33	..	..	..
Goudhurst	Radiation	2·0	1·1	0·6	0·3	0·1
	Wind	0·7	0·5	0·1	0	0
	Total	2·7	1·6	0·7	0·3	0·1
	Wind/total (%)	26	30	..	..	..
PLAIN						
East Malling	Radiation	1·5	0·9	0·4	0·1	0
	Wind	0·5	0·3	0·1	0·1	0
	Total	2·0	1·2	0·5	0·2	0
	Wind/total (%)	23	25	..	..	..
Wye	Radiation	1·1	0·6	0·2	0·1	0
	Wind	0·2	0·1	<0·1	0	0
	Total	1·3	0·7	0·2	0·1	0
	Wind/total (%)	14	13	..	..	..
COAST						
Margate Ramsgate Folkestone				Nil		
Deal	Radiation	0·1	<0·1	0	0	0
	Wind	0·1	0	0	0	0
	Total	0·2	<0·1	0	0	0
	Wind/total (%)	40	0	..	..	..
Dover	Radiation	<0·1	0	0	0	0
	Wind	0	0	0	0	0
	Total	<0·1	0	0	0	0
	Wind/total (%)	0	—	..	..	..
Dungeness	Radiation	0·4	0·3	0·1	<0·1	0
	Wind	0·1	<0·1	<0·1	0	0
	Total	0·5	0·3	0·1	<0·1	0
	Wind/total (%)	19	10	..	..	..

Entries of <0·1 indicate frequencies >0 and <0·05.

Apparent discrepancies are due to the fact that the lines giving total frost frequency and wind/total (%) have been worked from the total frequencies and not from the mean frequencies of radiation and wind frost.

ERRATUM

January 1950, page 20, line 30; *delete* "over which there was stable air."

METEOROLOGICAL OFFICE DISCUSSION

December 5, 1949. The significance of three-dimensional weather analysis in forecasting. By R. Scherhag (Neue Methoden der Wetteranalyse und Wetterprognose, Berlin, 1948, p. 318.) Opener—Mr. J. L. Galloway.

Dr. J. M. Stagg, Principal Deputy Director of the Meteorological Office, intimated the Director's regret at being unable to be present, and called on Mr. J. L. Galloway to open the discussion.

Mr. Galloway stated that it was not his purpose to attempt to review the whole of Scherhag's book. Reviews had already appeared in the *Meteorological Magazine*[1]* and the *Quarterly Journal of the Royal Meteorological Society*[2]. He proposed to confine himself to those parts of the book in which Scherhag dealt with the use of upper air data in forecasting.

In Mr. Galloway's view, the differences between our own forecasting technique and that of the Germans were more a matter of practice than principle. Like ourselves, the Germans worked on the concept of thermal steering, as embodied in upper flow patterns and thicknesses. It appeared to him, however, that the Germans had not progressed in regard to the former as far as had Dr. Sutcliffe and his colleagues in the Forecasting Research Division at Dunstable; German effort had rather been directed towards the stratosphere where they had led us in the development of the radio-sonde. Herein lay what he considered was the main difference between the two techniques; the Germans had extended the scope of Bjerknes' rule, that a depression moved in the direction parallel to the surface isobars in the warm sector, to the generalization that a depression was steered by the pressure pattern at the lowest level which it did not disturb. Thus, while in both techniques the contours of the 500-mb. level were used for steering, the Germans had no hesitation in using the contours for a higher level, when, as sometimes happened, use of the 500-mb. contours presented difficulties.

Mr. Galloway had been struck by the absence from the book of reference to any new theory. On the contrary, Scherhag had here and there claimed that the new upper air observational data had confirmed propositions, both theoretical and empirical, put forward in Germany years before. Scherhag's own theory of divergence, which had given him an international reputation, had been published in the early 1930's, before upper air charts were available. Scherhag had re-emphasised that simple fanning of isobars did not in itself constitute divergence; for this a removal of air was required. Ryd's postulate had provided a working hypothesis; Ryd had shown in 1927[3] that the deceleration which took place in such a situation caused in the northern hemisphere a deviation of the stream-lines toward higher pressure. Scherhag had applied this to account for cyclogenesis on the low-pressure side of what the Germans called the " delta " (exit) of a " frontal zone " which, in their terminology, was the zone of transition between two air masses of different origin which were in contact along a length of at least 1,000 Km. In this context we would have expected a discussion of jet streaming, but, although Scherhag was aware of the high winds experienced at upper levels in frontal zones, this was a term he did not use.

Another term, introduced by Mollwo in 1936[4], but unfamiliar to British meteorologists, was " stratospheric compensation ". This was applied to a number of empirical relationships which the Germans had developed between the temperature of the stratosphere and various parameters, *e.g.* the pressure at the surface and other levels, but Scherhag had not indicated whether this work had any general short-term prognostic value. One German writer[5] had found 11- and 22-day periodicities persisting for 3½–5 periods in departures from normal stratospheric compensation at Jever during the winter of 1947–48. In this connexion it was interesting to note that it had been suggested in America[6] that density change in the layer 2–3 Km. above the tropopause contributed most to pressure change at the surface.

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*The index numbers refer to the list of references on p. 54

The working methods used by the Germans in the routine construction of prebaratics were as follows:—

Surface prebaratics. The charts required were the analysed surface chart, the absolute and relative charts of the standard upper surfaces and the 24-hr. and 3-hr. isallobaric charts.

The basic data were the 24-hr. isallobars and the 500-mb. absolute contours. Arbitrary points on the isallobaric chart were advected in accordance with the direction and 50–60 per cent. of the speed given by the absolute contours at the chosen level. Changes in the isallobaric field were estimated from the pattern of the contours in accordance with empirical rules developed by Scherhag and others. The resulting pattern was smoothed to eliminate any features known to be impossible in nature. The forecast isallobaric chart was then added to the surface chart. A further adjustment might be necessary to fit in the surface fronts.

Upper-level prebaratics. The contours of the absolute topography were obtained by adding the forecast thicknesses to the surface prebaratic. In forecasting the change of thickness, consideration was given to the effects of radiation, convection and other vertical motions, and advection. The effect of radiation was negligible. The effects of convection, which might cause an error of up to 20 dynamic dekametres over the sea in winter, and of other vertical motions were not negligible and were not easily measurable. They were allowed for by adjusting the speed of advection, itself the most important single factor and the most readily susceptible to calculation, in accordance with the rule that the displacement of the relative isopleths was to a first approximation due to the gradient wind just above the surface friction layer and took place at a speed equal to 80 per cent. of the geostrophic value at that level.

Slides were then shown of three cases discussed by Scherhag:—

(*a*) December 5–6, 1942—stratospheric steering and influence on development.

(*b*) March 18–19, 1944—construction of prebaratics for March 19, illustrating the effect of (i) upper divergence and upper convergence and (ii) increase of horizontal temperature gradient.

(*c*) May 26–27, 1944—anticyclogenesis due to geostrophic departures.

In conclusion, Mr. Galloway said that Scherhag looked for improvement in the accuracy of forecasting to a better understanding of geostrophic departures which would come from a denser network of upper air stations.

Dr. Stagg, opening the discussion, said he wanted to know what use the Germans made of the departures from the normal stratospheric compensation.

Mr. C. S. Durst said that the charts mentioned were all available in the German daily weather reports. He expressed grave doubts as to whether these charts were as accurate as those now being published in the United Kingdom.

Mr. C. K. M. Douglas referred to the pioneer work carried out by the German meteorologists in the 1930's in the construction and interpretation of upper air charts, an achievement in which Dr. Scherhag had played a prominent part. The large number of aeroplane soundings made in Germany at that time had provided an opportunity of which good use had been made. He had always felt that the real value of empirical forecasting rules was somewhat limited. Thermal steering was an old principle, as Scherhag had pointed out, and there was obviously a real foundation for it, but if applied without great caution it might damage rather than improve the forecasts. A real advance would have to be based on an understanding of the dynamical and physical processes underlying the observed changes. He thought that the work carried out by Dr. Sutcliffe and his collaborators in the Forecasting Research Division had already rendered obsolete most of that part of Scherhag's book (only a fraction of the total) which dealt with forecasting. Although there was no doubt about the great importance of ageostrophic winds, it was premature to suppose that they could be applied directly to forecasting at present. In the case of May 26, 1944, if the British soundings were taken into account, the upper winds as plotted in the German daily weather report for that day gave no evidence of an outstanding or calculable ageostrophic motion. The alleged stratospheric steering, on December 5–6, 1942, was equally open to doubt. The rapid advance of the wedge could be better explained by the strong anticyclonic pattern in the 1000–500-mb. thicknesses associated with the very warm air to westward, which was rapidly approaching. Our own experience had shown conclusively that it was essential to take into account not only the existing thermal and flow patterns but also the probable future structure before the prebaratic was completed. The ideal plan was to make a rough prebaratic, then a pre-thickness chart based on it, and finally to adjust both together, but the clock was a limiting influence. The errors in a prebaratic increased in a roughly linear ratio to the time interval to which it referred, and if it was delayed too long its value was reduced. The high standard of the greater part of the book suggested that its author was more at home on the solid ground of fact than the quagmire of so-called forecasting rules. The book would be of value to meteorology even if it did not affect forecasting in this country. It would be a task of extreme difficulty to produce a text-book which could really influence forecasting.

Dr. R. C. Sutcliffe agreed that the slavish use of forecasting rules was unsatisfactory. Scherhag was an empiricist, but he had a reputation, outside as well as inside Germany, of being a very good practical forecaster. Dr. Sutcliffe missed any plausible general theory of forecasting in the book. The Germans had found cyclogenesis in the " delta " early in the 1930's and had made efforts to provide a theoretical foundation for it. Roediger had written on the vorticity aspect. Now the Germans had got away from pure frontal theory without considering dynamics. Scherhag had said nothing very clearly or effectively that was not already in our own vocabulary and we had little to learn from him. The area covered in his charts was far too small. The technique for the use of upper air charts had not yet been finally established, but at Dunstable they had settled down to using the 500-mb. level. If more than one level were to be used, the work would become complicated. In any case he did not like the mentality which could say " the 500-mb. level doesn't seem to give the answer to-day, let us have a go with the 225- or even 96-mb. level ". A paper on the use of upper charts had recently been completed at Dunstable and was being issued. The function of research was to feed professional forecasters with ideas ; it would be impossible to write a complete text-book of forecasting smaller in compass than the " Encyclopaedia Britannica".

Mr. J. S. Sawyer said that the broad lines of Scherhag's technique, although largely empirical, agreed with those developed at Dunstable from Dr. Sutcliffe's ideas. He pointed out the contrast between Scherhag's technique and that of Rossby who used the flow patterns for the 500- and 750-mb. levels.

Mr. E. Gold took exception to the statement about Scherhag's use for steering of the lowest level not affected by the disturbance being steered. He thought that this was absurd ; if the disturbance did not affect the level he did not see how the level could affect it. He inquired whether Scherhag had discussed the rate of decay of disturbances; Dr. Sutcliffe replied in the negative and remarked that it was time that the turbulence experts turned their attention to large-scale atmospheric friction.

Dr. Farquharson thought that the thickness-pattern method was more practically satisfactory than Scherhag's empiricism.

Mr. J. M. Craddock referred to Scherhag's appreciation of the problem of forecasting thickness change. In his view the effect of radiation was not negligible; in fact, it had been calculated by Brunt. The allowance for convection was, he thought from his own work, about right. He had also measured the advection contribution on 700 occasions for Downham Market, and had as a result formed the opinion, shared by the Upper Air Unit at Dunstable, that if change of thickness were to be allowed for by choice of the speed of advection of the isopleths, then 45 per cent. of the speed of the geostrophic wind just above the surface friction layer should be taken, not the 80 per cent. used by Scherhag.

Prof. P. A. Sheppard was disappointed that he had not learned more about " stratospheric compensation ". He sounded a warning note about the criticism of Scherhag's empiricism. Ryd had had the right ideas on the formation of depressions and these had been built on by Scherhag to give his work a theoretical basis. In any case all this took up only a small portion of a book which had to be regarded as a contribution of first importance to meteorological literature.

Dr. A. G. Forsdyke agreed that Scherhag had little to teach British forecasters, and supported Dr. Sutcliffe's view that only one parameter should be studied. Scherhag had failed to mention the effect of stability on disturbance development. Sumner had worked on this and had shown that the theory was in agreement with experience.

Mr. Galloway, in replying to the discussion (partly communicated) said that the Germans claimed for their radio-sonde an accuracy of more than twice that claimed by us for the Kew radio-sonde. The whole question of German requirements of accuracy of measurement in the upper air had been previously discussed in the Meteorological Office[7]. The completion of Scherhag's book had been sponsored by the American Occupation authorities in Germany, and it was therefore all the more regrettable that the German war-time charts published in it had not been corrected and amplified by using the British upper air data. In reply to Dr. Stagg and Prof. Sheppard he said that the Germans had applied the departures from the normal stratospheric compensation to the problem of the general circulation, but they had not yet decided whether the stratosphere played a primary or secondary role in the day-to-day regime of the weather. They appeared to have made no progress from Ertel's position in 1932[8]. Dr. Sutcliffe had recently dealt with the problem of empiricism in forecasting[9] and had suggested that " the most fertile line for early practical results lay along the extension of established channels, somewhere between pure empiricism and pure theory, what we may call rational empiricism ". He would like to add a final word—to the thickness school. Numerous empirical methods of getting near the future 30-hr. position of a depression had been tried out in the U.S. Weather Bureau[10] and better results had been obtained from the consideration of the surface isallobars than the upper contours.

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METEOROLOGICAL RESEARCH COMMITTEE

The seventh meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held on November 17, 1949.

Methods of analysing upper air observations climatologically were considered, especially the difficulties at the 200-mb. level due to the large variations in temperature which are related with variations in tropopause height. Day-to-day forecasting for the 200-mb. level was also discussed.

A paper on the advective temperature changes in the troposphere by Mr. J. M. Craddock[1] and some comments on it by Dr. A. H. R. Goldie[2] were discussed at length. The former paper provides data which should prove useful to the forecaster.

The errors of radar wind observations on ocean weather ships were also considered.

The eighth meeting of the Physical Sub-Committee was held on November 9.

The research programme of the Meteorological Research Flight was considered, and the Committee heard of the development of two new types of aircraft thermometer with smaller lag than the routine instrument. It was agreed that, in future, high-level ascents by the Flight for the purpose of measuring humidity should be made only in selected synoptic situations.

The present position of knowledge of the size of water drops occurring in nature was reviewed and it was agreed to lower the priority of this work.

Two papers by Mr. F. Pasquill, one dealing with evaporation from grassland[3] and the other with the aerodynamic drag of grassland[4], were considered.

The Committee also discussed clear-air turbulence and its effect on aircraft and the measurement of turbulence in the high atmosphere.

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[1] *Met. Res. Pap., London*, No. 517

[2] *Met. Res. Pap., London*, No. 518

[3] *Met. Res. Pap., London*, No. 498

[4] *Met. Res. Pap., London*, No. 503

ROYAL ASTRONOMICAL SOCIETY

A discussion on " Energy exchanges between the sea and the atmosphere " was held in the rooms of the Royal Astronomical Society on October 28, 1949 with Dr. G. E. R. Deacon, F.R.S., in the chair.

In his opening remarks Dr. Deacon mentioned that the problem of the energy exchange between the sea and the atmosphere was one which deeply concerned meteorologists and oceanographers alike. Whereas the meteorologist might say that the ocean received its energy from the atmosphere in the form of waves and currents the oceanographer in turn might say that the atmosphere largely derived its source of energy from the warmth of the oceans.

Prof. P. A. Sheppard opened the discussion by saying that the " air-ocean " was a mutually-reacting system. He discussed the equation of energy exchange between sea and air and estimated the magnitude of each term.

The stress coefficient had been computed using values of the strength of the wind on the water surface calculated from observations of the mean tilt of Lough Neagh in Northern Ireland. The stress coefficient agreed fairly well with other observations. It increased with unstable temperature gradient and decreased with stable gradient.

Mr. H. F. Bowden dealt with the hydrodynamical approach to the problem of heat exchange between the atmosphere and the sea and with practical attempts to apply the energy-balance equation.

Amongst contributors to the discussion were Mr. Charnock who described the Lough Neagh experiments and Prof. Neiburger who doubted the accuracy of the terms in the energy-balance equation. For example, the insolational term did not take into account reflection from clouds. Mr. Gold gave an interesting little calculation of the energy of waves breaking on the shore which, under assumptions of reasonable wave height and velocity, amounted to about 60 kilowatt-hours per centimetre of shore per day. This calculation served as an example to show that, although the energy derived from the frictional term in the energy-exchange equation was not negligible in itself, yet it could be neglected for Prof. Sheppard's purpose where the whole surface of the ocean was being considered.

Dr. Deacon, in summing up, said it was interesting to see how the actual routine observations made over the oceans could be of such use to meteorologists and oceanographers.

A. H. GORDON

PHYSICAL SOCIETY

Charles Chree Memorial Lecture

The Charles Chree Memorial lecture was given by Prof. G. M. B. Dobson before the Physical Society in the Science Museum on Friday November 4, 1949. The speaker was introduced by the President, Prof. G. I. Finch, who then presented Prof. Dobson with the Charles Chree gold medal and prize.

Prof. Dobson began entertaining the audience with reminiscences of Dr. Chree at Kew Observatory. Dr. Chree had always placed great emphasis on the importance of experimental evidence.

When he (the speaker) had known Dr. Chree at Kew, experimental facts were greatly lacking in all branches of meteorology, especially with regard to the upper atmosphere, and today there is still much work to be done in such subjects as atmospheric electricity, visibility and the light-scattering properties of the atmosphere.

The second part of Prof. Dobson's lecture consisted of a history of research into the ozone content of the atmosphere, a subject to which he has contributed so much. He concluded it with the interesting statement that Sir Charles Normand is now arranging for systematic world-wide observations to be made with the Dobson ozone spectrophotometer.

The last part of the lecture dealt with the measurement of the water content of the atmosphere at very low temperatures with the Dobson-Brewer frost-point hygrometer and the recent cloud-chamber work at Oxford by Cwilong and others on condensation processes.

Sir David Brunt, who spoke of his long association with the lecturer, proposed a vote of thanks to Prof. Dobson.

OFFICIAL PUBLICATIONS

British Rainfall 1940–42

This volume treats of the rainfall of Great Britain and Northern Ireland during the first three of the six war years when the annual publication of *British Rainfall* was suspended. The essential features of pre-war volumes have been retained in the new publication, but considerable curtailment and re-arrangement have been necessary to summarise adequately so many data within a single volume. The tabular matter is sufficiently complete to facilitate comparison with earlier years.

In Part I the distribution of rainfall in the months, the seasons and the year is considered in its relation to the average for 1881–1915. There are chapters on various features of rainfall, including spells of dry and wet weather, intense falls, duration of rainfall and evaporation. This part also includes 55 maps, of which three are coloured plates. The General Table, which forms Part II, gives the annual totals of rainfall and the numbers of rain days at nearly 5,000 stations which were maintained throughout the three years.

It is expected that the volume of British Rainfall for 1943–45 will be published shortly. The series up to the volume for 1946 will then be complete.

Average Annual Rainfall over Great Britain

Maps of average annual rainfall, 1881–1915, over Great Britain on a scale of about 10 miles to 1 inch have now been published by the Ordnance Survey.

Sheet 1 covers Scotland and northern England as far south as Ravenglass to Scarborough, and Sheet 2 the remainder of England and Wales. They are published in colour and cost 5*s*. 0*d*. net. each.

The first attempt at a rainfall map of the British Isles appears to have been that published by Mr. Joseph Atkinson of Harraby, near Carlisle, in 1841 or 1842. Petermann's "Hydrographical Map of the British Isles", published in July 1849, gives plotted averages for 113 places, practically all of which had less than 50 in. Later a small-scale map was published in Bartholomew's "Physical Atlas" Vol. III, 1899, giving isohyetal lines for 25, 30, 40, 60 and 80 in. This now can be regarded as little more than a sketch map depicting the relatively dry and wet areas.

The present map replaces that published in the "Rainfall Atlas of the British Isles" by the Royal Meteorological Society in 1926, on a scale of 60 miles to 1 inch, drawn originally in the Meteorological Office, on a scale of 19 miles to 1 inch. It was appreciated at the time that the ideal arrangement was to prepare maps on a scale of 2 miles to 1 inch, but that this would take a good deal of time. In order to produce a map for the Atlas quickly various short cuts were adopted. The isohyetal lines were based on information obtained from three sources:—

(*a*) Averages for 1881–1915 for 578 stations prepared in the Meteorological Office and published in the "Book of Normals", Section V.

(*b*) Maps on a scale of 2 miles to 1 inch prepared by Dr. H. R. Mill for the Geological Survey between 1908 and 1916. The averages were usually for the 35 years 1868–1902 and the lines were modified to fit the values for 1881–1915 by reference to the available averages over the area for the later period. These maps covered in all about half the area of the British Isles.

(*c*) Weighting decadal means for stations not covered under (*a*) to give approximate values for 1881–1915. This gave some 1,100 averages. In all the map was based on averages, actual or computed, for some 3,000 stations. It is interesting to recall that when this map was published initially* an estimate was given that the time taken by the observers in making the daily observations to enable the average rainfall map to be prepared was equivalent to a year's work for 500 men. A tribute should therefore be paid to the patient work of the large body of voluntary rainfall observers, and their public spirit in forwarding a copy of their readings to the Meteorological Office, which makes possible the preparation of the rainfall maps.

The distribution on the present map is indicated by means of isohyetal lines for 20, 22·5, 25, 27·5, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 120 and 150 in., the heavier rainfall being indicated by darker shades of blue. The fluctuations of monthly rainfall at representative stations are shown by means of dispersion graphs. There are 16 such graphs on Sheet 1 and 10 on Sheet 2. For each such station the monthly amounts within the period 1881–1915 are represented by dots. The monthly averages, the median (or mean value) and the upper and lower quartiles are also indicated.

The isohyetal lines were originally prepared in the Meteorological Office on a scale of 2 miles to 1 inch. In order to retain as much detail as possible the isohyetal lines were copied first, by the Ministry of Town and Country Planning, on

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*See *Quart. J. R. met. Soc., London*, **47**, 1921, p. 101.

to maps on a scale of 4 miles to 1 inch before preparing the final copies for reproduction. The rainfall survey on a scale of 2 miles to 1 inch, using the mean 1881–1915, was commenced soon after 1920 and gradually extended county by county to cover the 74 sheets of the Ordnance Survey of Great Britain on this scale. Where a record was complete for the 35 years, 1881–1915, the mean annual amount was used. Wherever a rainfall record had been maintained for a shorter period, but for at least five years, the probable annual average, 1881–1915, was computed by multiplying the observed mean by a factor, derived from adjacent long records, to make allowance for the short record having either a preponderance of wet or dry years. Records maintained both before 1881 and after 1915 were used. The procedure is explained in an article on " The Rainfall of Norfolk ", *British Rainfall*, 1928 (p. 270). In all, averages were computed for some 20,000 stations in the United Kingdom. The article in *British Rainfall*, 1933 (p. 266) on the rainfall of the County of London shows that averages can be obtained of sufficient accuracy to draw isohyetal lines at intervals of 1 inch, but in the mountainous regions the variation in the rainfall from place to place is often so great, and the records relatively so few, that it is only practicable to draw the lines at greater intervals. In the regions of heavier rainfall the isohyetal lines are therefore likely to require revision as more information becomes available.

Before the maps could be drawn with any degree of confidence it was necessary to have a clear picture of the errors arising in rainfall recording, and also of the relation of the distribution of rainfall to the orography. The inspection of numerous rain-gauges and examination of their records enabled the extent of any errors to be defined quantitatively and those of appreciable magnitude to be eliminated. The main source of error arose from abnormal exposures, especially on windward slopes, so that many mountain rain-gauges had to be inspected and often more orthodox sites selected. The second technique was developed by studying the distribution in areas of abundant data and applying this knowledge to areas of few records. The most exciting occasions involved making a forecast, for water-supply schemes, of the probable distribution over a mountainous catchment area with no records, setting up rain-gauges, and, when 5–10 years' records became available, plotting the computed averages and noting what modifications were necessary in the original provisional distribution. In the same way when a gauge was moved, the effect on the catch was closely studied to see whether the distribution on the map required modification. This is one of the reasons why the preparation of the complete rainfall survey of Great Britain has been spread over so long a period.

The present map, which itself has taken some 30 years to complete, may be regarded as the fulfilment of an ambition conceived more than 100 years ago. It is the result of the steady application of the British Rainfall Organization, Meteorological Office. Credit is also due to the Maps Section of the Ministry of Town and Country Planning and to the Ordnance Survey for the excellent reproduction.

J. GLASSPOOLE

LETTER TO THE EDITOR

Definition of relative humidity

The definition of relative humidity given in Resolution 166 of the Conference of Directors, Washington, 1947 is as follows: " The relative humidity *U* (in per cent.) of moist air is defined by $U = 100r/r_w$ where r is the mixing ratio of moist air at pressure p and temperature T, and r_w is the saturation mixing ratio at the same pressure and temperature ".

It follows from this and the definitions of r, r_w and of vapour pressure that

$$U = \frac{e'}{e} \times \frac{p-e}{p-e'} \times 100$$

where e' is the actual vapour pressure and e is the saturation vapour pressure.

Hitherto U has been defined either (*a*) as the ratio (expressed as a percentage) of the water vapour actually present in unit volume to that contained in unit volume of saturated air at the same temperature, or (*b*) as $100e'/e$. These are identical over the range of values of temperature of water vapour for which Boyle's law, pv = const., applies.

They are both materially different from the new value. For example at a temperature of 80°F. and pressure 1000 mb. and a vapour pressure of 17·5 mb. the new definition gives 49 per cent. instead of 50 per cent. given by the former definitions. At a temperature of 120°F. and a vapour pressure of 58·4 mb. the corresponding figures are 47 per cent. instead of 50 per cent. Higher temperatures than 120°F. are not common meteorologically, but they may occur in other connexions where relative humidity is significant, and it would not be desirable to have a different definition for these higher temperatures. At 185°F. and a vapour pressure of 350 mb. the new definition gives 23 per cent. against 50 per cent. by the old definitions.

If the total pressure p were 500 mb. instead of 1000 mb. the difference between the old and new values of relative humidity would be even more marked.

It seems unlikely that so great a change from past practice was intended and perhaps there is some other interpretation of the new definition.

E. GOLD

8 Hurst Close, London, N.W.11, November 25, 1949

NOTES AND NEWS

Universal Decimal Classification

551.5 Meteorology

In 1935 the Meteorological Section of the Universal Decimal Classification was greatly improved and enlarged by the Commission for Bibliography and Publications of the International Meteorological Organization, and was recommended for general use by the Conference of Directors at Warsaw that year by Resolution Warsaw 1935 : 101. It was brought into use in the Meteorological Office Library on January 1, 1936.

The classification as arranged in 1935 is described in publications numbered 1, 2 and 3, in the list of references on p. 60. A few additions were made at Berlin in 1939 by Resolution Berlin 1939 : 39 of the International Meteorological Committee and the amended classification as it existed from then onwards until 1949 is given in reference 4.

The progress of meteorology since 1939 has naturally necessitated a revision of the classification and the necessary changes were worked out by the Commission at its meeting at Toronto in September 1947. The proposals made (reference 5) were accepted by the Conference of Directors at Washington in October 1947 in Resolution Washington 1947 : 120, and were then discussed between the Commission and the International Federation of Documentation which is responsible for securing that the classifications of individual subjects in the Universal Decimal Classification are in conformity with the general plan. Certain amendments of detail were made as a result of these discussions and the International Meteorological Organization is to publish an amendment to Publication 61 describing them.

The revised classification will be brought into use by the Meteorological Office Library for classifying books and papers received on and after January 1, 1950. By agreement with the British Standards Institution, which holds the copyright of the Universal Decimal Classification in Great Britain, a mimeographed copy of the revised classification has been sent to all recipients of the Library's Monthly Bibliography.

The major changes are those made to allow of more detailed classification in:—

551.501. *Methods of Observation.* New numbers added under 551.501.8 to cover meteorological observations by radar and location of sources of atmospherics.

551.507. *Apparatus and methods for carrying or supporting meteorological instruments.* New group added to cover special balloons, aircraft, etc.

551.508. *Meteorological instruments.* Additions to cover new instruments, such as cloud searchlights, and radar instruments.

551.509. *Weather forecasts and other applications.* Detailed expansion especially of 551.509.6 artificial influences (*e.g.* protection against frost, fog dispersal).

551.521. *Radiation and temperature.* Expansion, to give more exact distinction between radiations of different wave-lengths.

551.557. *Upper winds.* Expansion, to cover diurnal, annual and secular variations, frequencies and wind roses.

551.558. *Vertical component of air motion.* This is a new group.

551.584. *Microclimatology.* Addition of a detailed subdivision, and of " Mesoclimatology ".

551.586. *Bioclimatology.* This group has been subdivided in detail.

551.589. *Synoptic climatology.* A new group has been added to cover this concept.

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5. Lausanne, Organisation Météorologique Internationale. Commission de bibliographie et de publications. 2me session, Toronto, Canada, 1947, Rapport final abrégé. *Publ. Org. mét. int., Lausanne,* No. 61, 1949. This publication will, it is understood, be amended to incorporate the changes agreed with the Fédération Internationale de Documentation.

NEWS IN BRIEF

The following awards to members of the staff of the Meteorological Office were announced in the New Year Honours List, 1950:—

O.B.E.

Mr. R. P. Batty.	Assistant Director.

M.B.E.

Mr. A. M. Young.	Experimental Officer, serving with British Air Forces of Occupation, Germany.

OBITUARIES

Mr. Arthur Eastwood.—We regret to learn of the death on October 7, 1949, in his ninetieth year, of Mr. Arthur Eastwood. In 1901 Mr. Eastwood set up a rain-gauge at Leigh Court, Angersleigh, and maintained records there continuously until June 1946, when he moved to Trull, two miles nearer Taunton. He continued to record daily rainfall measurements and personally wrote out and sent copies of the observations to the Meteorological Office to within a month of his death.

Mr. William Melvill Coode.—The death on October 26, 1949, of Mr. W. M. Coode, in his eighty-fourth year, removes from the ranks of rainfall observers one whose interest in weather recording extended over more than half a century. Since 1898 Mr. Coode had carried on without a break the rainfall record which his father commenced at St. Austell, Trevarna, in 1864. The records have been included in the annual volumes of *British Rainfall* for more than eighty years. This long homogeneous record was selected for use in many investigations, *e.g.* the percentage of average annual rainfall falling in the driest and wettest groups of consecutive months of varying length.

WEATHER OF DECEMBER 1949

Mean pressure was between 1020 and 1025 mb. in an area which included part of western France, the Azores, Bermuda, Nova Scotia and the eastern half of the U.S.A., and which reached the Pacific coast of America in about latitude 42°N. Over much of this area mean pressure was from 3 to 7 mb. above the average. Mean pressure was generally below 1000 mb. in an area bounded by Greenland in the west and the Gulf of Bothnia in the east and extending from northern Scotland nearly to Spitzbergen; over the part of this area lying between Iceland and northern Norway it was below 995 mb., and was 10 mb. or more below the average.

The weather over the British Isles was mainly mild, with southerly or westerly winds predominating. It was drier than usual south of an irregular line stretching from the Humber to Pembrokeshire and in a narrow coastal belt in east Scotland. It was very dry (less than half the average) over much of south-west England and in the neighbourhood of Aberdeen. On the other hand it was very wet in the west and north, particularly in an area extending from the north of Scotland to south Lancashire, over an inland area in north Wales and in County Tyrone.

During the opening days depressions moved north-east or east off the north of Scotland, while troughs or secondary depressions crossed the British Isles. The secondary which moved across north Ireland and north England on the 3rd and 4th was associated with gales, severe locally, and heavy rain in the north-west and west; for example, 2·20 in. at Blaenau Festiniog, Merioneth, on the 2nd and 2·26 in. at Borrowdale, Cumberland, on the 3rd. On the 6th a depression in mid Atlantic rapidly approached the Hebrides and on the 7th it moved to north of the Shetlands and thence to north-west Norway; rain fell generally on the 6th and was heavy in the north-west (2·28 in. at Ardgour House, Argyllshire), while strong winds and gales occurred at exposed stations. In the rear of this depression a small polar disturbance formed off the north of Scotland on the 8th in a strong northerly air stream and subsequently moved south and later south-east over our western districts giving widespread snow or sleet; a blizzard was reported at Duntuilm on the 9th and there was heavy drifting in the western Highlands and on the Welsh Hills. The polar air caused a considerable fall in temperature over the country and the period 8th–11th or 12th was cold. On the 11th and 12th a wedge associated with the Azores anticyclone moved south over the British Isles; mainly fair weather prevailed over most of England and Wales but moderate rain occurred in north-west Scotland on the 11th and in Scotland and the north of Ireland on the 12th. On the 13th a trough moving south-east over the British Isles gave rain in most parts. Subsequently a mild, unsettled south-westerly type was renewed; on the 14th and 15th a secondary depression moved across Scotland giving almost general rain on the 14th and showers with local hail on the 15th, while on the 16th and 17th showery conditions prevailed as troughs to a depression near Iceland crossed the country. On the 18th and 19th a very deep depression moved from mid Atlantic across the north of Scotland; rainfall was general and heavy locally (2·35 in. at Ardgour House on the 19th) and there were widespread gales, severe in places, from the 17th–19th. On the 22nd an Atlantic depression moved north-east to Iceland where it remained, becoming less deep, until the 25th. Meanwhile an anticyclone over the Bay of Biscay moved east-north-east to Central Europe. A very mild air stream covered the British Isles; slight rain occurred generally on the 22nd but on the following days it was mainly dry in the south and east though rainfall was heavy at times in the north-west, notably on the 24th and 25th (3·51 in. at Ardgour and 2·97 in. at Onich on the 24th, 2·89 in. at Borrowdale and 2·20 in. at Blaenau Festiniog on the 25th). On the 26th yet another Atlantic depression moved north-east to the Shetlands causing further rain in the north-west and west. From the 27th–29th pressure was high over France and low to the north of the British Isles; dry weather prevailed for the most part in England and Wales but rain fell at times in Scotland and Ireland. During the closing days a deep depression off Portugal moved rather quickly north off our western seaboard causing some rain in the extreme south-west of the British Isles, while feeble fronts caused rain locally in Scotland and north Ireland.

The general character of the weather is shown by the following provisional figures.

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	59	23	+2·4	87	−1	121	21
Scotland	57	16	+0·2	143	+4	102	16
Northern Ireland..	54	22	+1·0	136	+4	79	13

RAINFALL OF DECEMBER 1949

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	1·40	59	*Glam.*	Cardiff, Penylan ..	4·18	83
Kent	Folkestone, Cherry Gdns.	2·09	65	*Pemb.*	St. Ann's Head.. ..	3·58	75
,,	Edenbridge, Falconhurst	1·48	45	*Card.*	Aberystwyth	4·73	119
Sussex	Compton, Compton Ho.	3·19	74	*Radnor*	Tyrmynydd	9·11	111
,,	Worthing, Beach Ho. Pk.	2·04	68	*Mont.*	Lake Vyrnwy	12·02	172
Hants.	Ventnor, Roy. Nat. Hos.	2·79	85	*Mer.*	Blaenau Festiniog ..	19·69	155
,,	Bournemouth	1·97	51	*Carn.*	Llandudno	4·09	141
,,	Sherborne St. John ..	1·70	52	*Angl.*	Llanerchymedd ..	4·49	102
Herts.	Royston, Therfield Rec.	1·59	69	*I. Man.*	Douglas, Borough Cem.	5·17	105
Bucks.	Slough, Upton	1·55	61	*Wigtown*	Port William, Monreith	5·09	112
Oxford	Oxford, Radcliffe ..	1·34	54	*Dumf.*	Dumfries, Crichton R.I.	7·05	165
N'hant	Wellingboro', Swanspool	1·44	61	,,	Eskdalemuir Obsy. ..	12·01	172
Essex	Shoeburyness	·98	53	*Roxb.*	Kelso, Floors	2·85	123
Suffolk	Campsea Ashe, High Ho.	1·65	72	*Peebles.*	Stobo Castle	6·02	158
,,	Lowestoft Sec. School ..	1·70	73	*Berwick*	Marchmont House ..	3·04	108
,,	Bury St. Ed., Westley H.	1·73	72	*E. Loth.*	North Berwick Res. ..	2·80	130
Norfolk	Sandringham Ho. Gdns.	1·57	62	*Midl'n.*	Edinburgh, Blackf'd. H.	3·85	165
Wilts.	Bishops Cannings ..	1·89	58	*Lanark*	Hamilton W. W., T'nhill	7·44	173
Dorset	Creech Grange ..	2·37	54	*Ayr*	Colmonell, Knockdolian	5·28	95
,,	Beaminster, East St. ..	1·81	38	,,	Glen Afton, Ayr San. ..	12·03	188
Devon	Teignmouth, Den Gdns.	1·47	35	*Bute*	Rothesay, Ardencraig ..	8·63	158
,,	Cullompton	2·13	48	*Argyll*	L. Sunart, Glenborrodale	12·63	145
,,	Barnstaple, N. Dev. Ath.	3·03	68	,,	Poltalloch	9·58	150
,,	Okehampton, Uplands	3·78	54	,,	Inveraray Castle ..	18·01	181
Cornwall	Bude School House ..	2·93	67	,,	Islay, Eallabus	8·80	148
,,	Penzance, Morrab Gdns.	4·06	71	,,	Tiree	6·90	132
,,	St. Austell	3·01	49	*Kinross*	Loch Leven Sluice ..	4·93	125
,,	Scilly, Tresco Abbey ..	2·28	49	*Fife*	Leuchars Airfield ..	1·66	67
Glos.	Cirencester	1·42	42	*Perth*	Loch Dhu	7·46	74
Salop	Church Stretton ..	2·93	83	,,	Crieff, Strathearn Hyd.	5·89	131
,,	Cheswardine Hall ..	2·26	80	,,	Pitlochry, Fincastle ..	5·13	127
Staffs.	Malvern, Free Library	1·46	53	*Angus*	Montrose, Sunnyside ..	1·84	66
Worcs.	Birmingham, Edgbaston	1·63	61	*Aberd.*	Braemar	4·87	137
Warwick	Thornton Reservoir ..	1·80	67	,,	Dyce, Craibstone ..	1·53	45
Leics.	Boston, Skirbeck ..	1·28	60	,,	Fyvie Castle	1·48	43
Lincs.	Skegness, Marine Gdns.	1·55	70	*Moray*	Gordon Castle	4·95	184
,,	Mansfield, Carr Bank ..	2·33	80	*Nairn*	Nairn, Achareidh ..	4·65	227
Notts.	Buxton Terrace Slopes	7·13	126	*Inv's*	Loch Ness, Foyers ..		
Ches.	Bidston Observatory ..	3·76	142	,,	Glenquoich	24·24	165
Lancs.	Manchester, Whit. Park	4·93	152	,,	Fort William, Teviot ..	18·00	176
,,	Stonyhurst College ..	8·44	174	,,	Skye, Duntuilm ..	8·99	144
,,	Blackpool	5·00	153	*R. & C.*	Tain, Tarlogie House ..	5·67	200
Yorks.	Wakefield, Clarence Pk.	2·30	95	,,	Ullapool	7·78	128
,,	Hull, Pearson Park ..	2·64	110	,,	Applecross Gardens ..	10·64	165
,,	Felixkirk, Mt. St. John	2·28	95	,,	Achnashellach	17·07	180
,,	York Museum ..	1·91	85	,,	Stornoway Airfield ..	8·44	142
,,	Scarborough	2·58	108	*Suth.*	Loch More, Achfary ..	20·15	218
,,	Middlesbrough.. ..	2·13	110	*Caith.*	Wick Airfield	3·89	126
,,	Baldersdale, Hury Res.	7·13	192	*Shet.*	Lerwick Observatory ..	5·81	121
Nor'ld	Newcastle, Leazes Pk.	2·40	102	*Ferm.*	Crom Castle	6·06	146
,,	Bellingham, High Green	5·05	139	*Armagh*	Armagh Observatory ..	4·58	146
,,	Lilburn, Tower Gdns. ..	2·71	103	*Down*	Seaforde	3·12	100
Cumb.	Geltsdale	5·77	151	*Antrim*	Aldergrove Airfield ..	3·84	112
,,	Keswick, High Hill ..	10·66	160	,,	Ballymena, Harryville	5·09	102
,,	Ravenglass, The Grove	6·17	135	*Lon.*	Garvagh, Moneydig ..	5·92	148
Mon.	Abergavenny, Larchfield	2·13	48	,,	Londonderry, Creggan	7·04	161
Glam.	Ystalyfera, Wern House	8·19	98	*Tyrone*	Omagh, Edenfel ..	7·34	174

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, AUGUST 1949

STATIONS	PRESSURE		TEMPERATURES							REL-ATIVE HUM-IDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Per-centage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1019·6	+4·7	83	47	73·8	56·1	64·9	+2·7	58·3	70	5·4	1·50	−0·74	8	7·3	50
Gibraltar	1016·5	0·0	99	67	86·5	73·2	79·9	+3·9	73·2	75	3·5	0·15	—	1	10·1	75
Malta	1016·8	+2·0	94	63	84·7	70·0	77·3	−1·8	70·6	56	1·0	0·05	—	1	11·9	88
St. Helena	1019·0	−0·9	66	52	63·1	53·9	58·5	+1·2	54·2	95	7·6	3·31	+0·71	20	—	—
Lungi, Sierra Leone	1013·4	—	85	71	81·6	73·1	77·3	—	73·9	92	7·2	32·05	—	28	2·9	23
Lagos, Nigeria ..	1013·6	+0·7	85	65	87·3	69·0	78·1	+0·2	74·6	88	7·3	3·13	—	17	3·6	29
Kaduna, Nigeria ..	1011·8	—	86	63	80·6	66·8	73·7	−0·5	69·9	86	7·4	10·82	−1·50	17	4·4	35
Chileka, Nyasaland	1019·8	−1·6	93	53	80·4	57·5	68·9	+1·7	58·0	58	1·5	0·00	−0·08	0	8·6	74
Lusaka, Rhodesia ..	1016·5	−1·2	93	45	83·0	54·6	68·8	+3·3	53·8	51	0·8	0·00	0·00	0	10·2	88
Salisbury, Rhodesia	1019·2	−1·5	88	39	76·7	48·3	62·5	+2·4	49·8	50	0·9	0·00	−0·10	0	9·6	84
Cape Town	1019·4	−0·9	73	42	63·8	49·5	56·7	+1·1	48·9	73	4·4	3·76	+0·39	16	—	—
Palmietfontein, S. Africa	1022·9	—	79	28	69·4	38·1	53·7	—	41·0	55	2·0	0·00	—	0	9·8	—
Mauritius	1019·3	−1·3	81	53	77·4	60·6	69·0	+0·5	63·3	72	4·2	1·00	−1·25	14	7·7	68
Calcutta, Alipore Obsy.	1000·7	0·0	94	75	89·7	79·5	84·6	+1·4	80·3	83	6·9	7·31	−6·07	23	3·8	29
Bombay	1004·6	−1·3	89	74	85·8	76·8	81·3	+0·5	77·5	86	6·4	15·22	+0·77	28	3·3	26
Madras	1005·2	−0·3	96	73	92·5	77·3	84·9	−1·1	76·0	77	6·9	5·21	+0·67	16	5·8	46
Colombo, Ceylon ..	1009·0	−0·3	87	73	85·2	77·7	81·5	+0·3	77·1	84	6·6	4·82	+1·58	19	6·1	50
Singapore	1009·7	+0·2	90	73	87·5	76·4	81·9	+0·8	76·6	79	6·5	3·19	−4·76	14	7·1	59
Hongkong	1006·1	+1·3	91	74	87·2	77·9	82·5	+0·4	78·3	87	—	14·07	−0·33	26	5·2	40
Sydney, N.S.W. ..	1023·2	+5·0	74	42	64·4	47·4	55·9	+0·9	48·9	71	3·7	5·06	+2·09	10	6·8	63
Melbourne	1022·1	+4·1	69	34	59·4	41·7	50·5	−0·5	44·6	67	5·0	0·99	−0·88	8	5·6	52
Adelaide	1022·6	+3·4	75	37	62·3	46·2	54·3	+0·3	48·2	61	4·0	1·51	−1·03	11	5·7	53
Perth, W. Australia	1017·2	−1·7	81	44	66·7	51·2	58·9	+2·9	55·4	75	5·0	6·67	+1·02	22	5·3	49
Coolgardie	1019·2	−0·1	81	35	67·9	44·9	56·4	+2·8	49·5	64	3·2	1·67	+0·68	7	—	—
Brisbane	1022·5	+3·3	78	42	70·2	49·2	59·7	−0·7	53·1	62	2·9	0·20	−1·81	4	7·8	70
Hobart, Tasmania																
Wellington, N.Z. ..	1014·6	−0·3	56	35	52·2	42·7	47·5	+0·2	45·0	80	5·0	4·42	−0·07	15	4·8	46
Suva, Fiji	1014·1	−0·1	84	63	78·1	68·8	73·5	−0·1	69·4	80	6·0	7·74	−0·55	17	4·5	39
Apia, Samoa ..	1013·2	+1·3	87	69	85·5	73·6	79·5	+1·0	76·0	78	4·4	6·28	+2·50	16	8·0	68
Kingston, Jamaica	1014·1	+0·6	94	72	90·2	74·5	82·3	+0·8	75·5	74	3·0	2·07	−1·48	9	8·4	66
Grenada, W. Indies	—	—	91	69	86·0	75·0	80·5	+0·8	76·0	83	5·0	6·23	−3·10	24	—	—
Toronto	1016·0	+0·6	99	50	82·8	63·4	73·1	+5·9	61·8	77	3·9	1·43	−1·36	7	9·5	68
Winnipeg	1014·0	+0·8	105	38	82·7	57·9	70·3	+6·5	58·3	86	4·3	2·27	+0·11	6	10·0	69
St. John, N.B. ..	1014·2	−1·1	87	47	73·6	56·8	65·2	+4·6	59·8	83	6·0	2·70	−1·16	14	7·5	53
Victoria, B.C. ..	1017·2	+0·3	80	48	68·1	51·2	59·7	0·0	52·4	92	6·4	0·84	+0·20	10	7·6	53

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NEW VERSION OF THE HUMIDITY SLIDE-RULE

By E. G. BILHAM, B.Sc., D.I.C.

Summary.—By extending the scales to low temperatures and by making some changes in the general lay-out, provision is made in the humidity slide-rule Mk. III for computing dew points down to −50°F., using data derived from surface observations, aircraft observations or radio-sonde. Scales for the computation of vapour density, vapour pressure, mixing ratio, relative humidity and hoar-frost point are also provided.

History.—In the first version of the humidity slide-rule,* provision was made for computing the usual hygrometric elements from psychrometric data within the ranges: dry bulb, 10° to 110°F.; wet bulb and dew point, 5° to 80°F. For temperatures below freezing point the dew point and relative humidity were defined with reference to saturation over supercooled water. This slide-rule was given the nomenclature Mk. I. In a tropical model, Mk. IA, the dry-bulb and wet-bulb scales were extended to 140°F. and 95°F. respectively. In 1940, the Meteorological Office changed its practice in regard to values below freezing point, and defined the relative humidity with reference to ice instead of supercooled water. At the same time it was decided to substitute the hoar-frost point (*i.e.* the temperature of saturation with respect to ice) for the true dew point (*i.e.* the temperature of saturation with respect to supercooled water). To cover these changes new patterns Mk. II and Mk. IIA (for the tropics) of the humidity slide-rule were introduced.

In 1947 the Twelfth Conference of Directors at Washingon agreed to define dew point and relative humidity with respect to water at all temperatures. The implementation of this decision meant that the Meteorological Office had to return to its pre-1940 practice. If no other considerations had been involved the action necessary as regards slide-rules would have been simply to re-introduce Mk. I and IA in place of Mk. II and IIA. The situation was, however, complicated by another factor. The Conference of Directors at Washington in 1947 had also recommended, as the basis of hygrometric computations, new tables of saturation vapour pressure (the Goff-Gratch Tables) which differed from those upon which the 1935 slide-rule was based.

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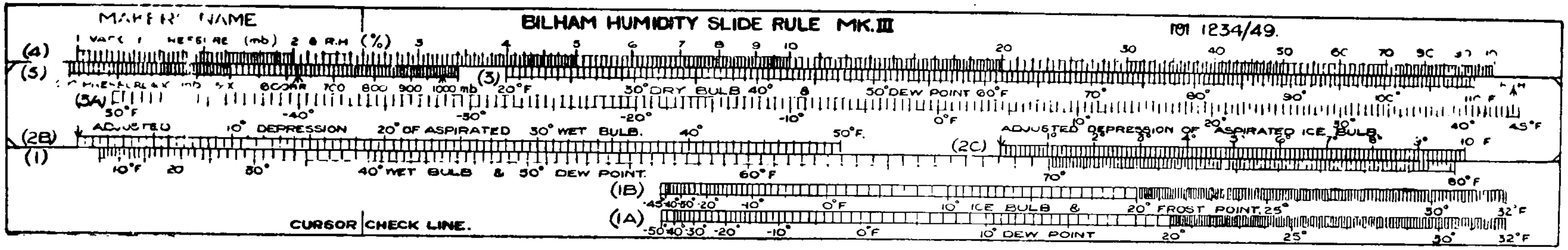
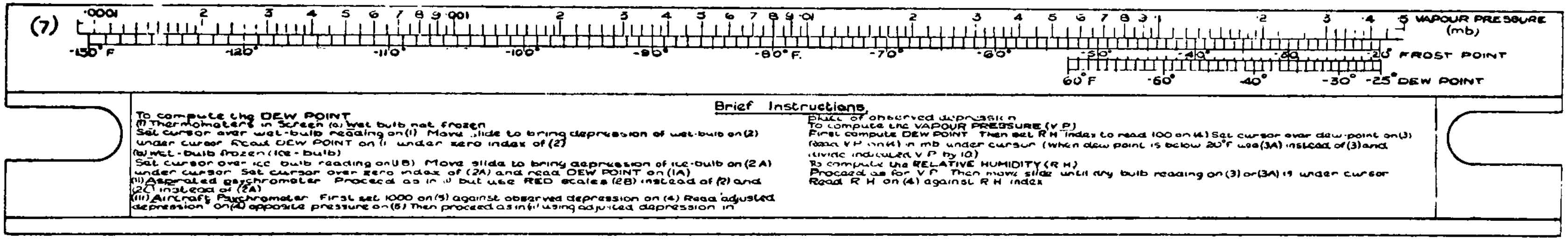
*BILHAM, E. G.; A humidity slide-rule. *J. Sci. Instr., London*, **12**, 1935, p. 318, and BILHAM, E. G.; A slide-rule for hygrometric calculations. *Met. Mag., London*, **70**, 1935, p. 254.


MAKERS' NAME
BILHAM HUMIDITY SLIDE RULE MK.III
1234/49.
(4)
(5)
(3)
(3A)
(2B)
(1)
(2C)
(1B)
(1A)
VAPOUR PRESSURE (mb)
R.H (%)
800 900 1000 mb
20°F
30° DRY BULB 40°
50° DEW POINT 60°F
ADJUSTED 10° DEPRESSION 20° OF ASPIRATED 30° WET BULB. 40° 50°F.
ADJUSTED DEPRESSION OF ASPIRATED ICE BULB.
10° F
45°F
40° WET BULB & 50° DEW POINT.
60°F
70°
80°F
10° ICE BULB & 20° FROST POINT 25°
10° DEW POINT
32°F
CURSOR CHECK LINE.

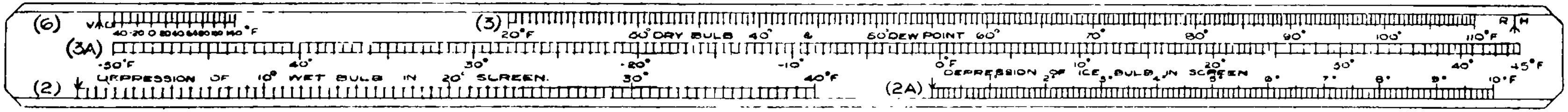

(7)
·0001
·001
·01
·1
·5 VAPOUR PRESSURE (mb)
-130°F
-120°
-110°
-100°
-90°
-80°F.
-70°
-60°
-50°
-40°
-30°
-20° FROST POINT
60°F
-60°
-40°
-30° -25° DEW POINT

Brief Instructions.

To compute the DEW POINT
(i) Thermometers in Screen (a) Wet bulb not frozen
Set cursor over wet-bulb reading on (1) Move slide to bring depression of wet-bulb on (2) under cursor Read DEW POINT on (1) under zero index of (2)
(b) Wet-bulb frozen (Ice-bulb)
Set cursor over ice bulb reading on (1B) Move slide to bring depression of ice-bulb on (2A) under cursor Set cursor over zero index of (2A) and read DEW POINT on (1A)
(ii) Aspirated psychrometer Proceed as in (i) but use RED scales (2B) instead of (2) and (2C) instead of (2A)
(iii) Aircraft Psychrometer First set 1000 on (5) against observed depression on (4) Read adjusted depression on (4) opposite pressure on (5) Then proceed as in (i) using adjusted depression in place of observed depression

To compute the VAPOUR PRESSURE (V P)
First compute DEW POINT Then set R H index to read 100 on (4) Set cursor over dew-point on (3) Read V P on (4) in mb under cursor (when dew point is below 20°F use (3A) instead of (3) and divide indicated V P by 10)
To compute the RELATIVE HUMIDITY (R H)
Proceed as for V P Then move slide until dry bulb reading on (3) or (3A) is under cursor
Read R H on (4) against R H index

BACK OF STOCK WITH SLIDE REMOVED.


(6)
VAC
(3)
(3A)
(2)
(2A)
20°F
60° DRY BULB 40°
60° DEW POINT 60°
110°F
R H
-50°F
40°
30°
-20°
-10°
0°F
10°
20°
40°
45°F
DEPRESSION OF 10° WET BULB IN 20° SCREEN. 30° 40°F
DEPRESSION OF ICE BULB IN SCREEN
10°F

REVERSE OF SLIDE.

FIG. I—LAY-OUT OF HUMIDITY SLIDE-RULE MK. III

Before slide-rules to meet the new international requirements could be obtained it thus became necessary to revise the specification. It was decided to undertake a more extensive revision so that the new design should provide means of reducing psychrometric observations made on aircraft at pressure levels up to 300 mb. and also for the conversion to dew point of relative-humidity observations provided by radio-sondes. These requirements are met in the Mk. III version now to be described. The necessary downward extension of the temperature scales gives the new pattern a further advantage over its predecessors, namely that it is capable of handling all but the most extreme readings obtained in high, middle and low latitudes.

In the new slide-rule the scales have been re-numbered, and there are many other changes from the previous design. The following description has therefore been written *ab initio*, no acquaintance with previous patterns being assumed.

General arrangements.—Following conventional practice the slide-rule (Fig. 1) comprises a fixed portion, the " stock ", 11 in. long by 1½ in. wide, a sliding portion the " slide ", and a cursor upon which is engraved a fine line at right angles to the axis of the stock. The slide is reversible and scales are engraved on both the front and the back. The remainder of the scales for most hygrometric computations appear on the front of the stock. On the back of the stock logarithmic scales of saturation vapour pressure for low-temperature ranges appear at the top, and the remainder of the space is occupied with abbreviated working instructions.

Imagining the slide-rule to be divided into two by a central axial line, the lower part is used for computing the dew point from psychrometric observations, and the upper part for converting dew point to vapour pressure and for computing relative humidity, mixing ratio and vapour density, or for inter-conversions of these parameters. There is provision also on the upper part of the rule for applying the pressure correction required when computing dew point from psychrometric observations provided by aircraft or high-level stations.

With one exception mentioned below the slide-rule provides, to three significant figures over most of the range, a direct solution of the relevant equation as internationally agreed. Unfortunately, there is as yet no international agreement as to the values of the so-called psychrometric constants. It is thus still possible for observers in different countries to derive slightly different values of the dew point, etc., from the same readings of dry-bulb and wet-bulb temperatures. The scales concerned are therefore based on values of the constants adopted by the Meteorological Office.

The exception referred to relates to the definition of relative humidity. Prior to the Conference of Directors at Washington in 1947 the relative humidity was defined as the ratio of the vapour pressure to the saturation vapour pressure at dry-bulb temperature, multiplied by 100. This was changed at Washington by substituting mixing ratio for vapour pressure. The numerical result is, at temperatures occurring in meteorological practice, very nearly the same with both definitions. The results agree at 100 per cent. and 0 per cent., and between these extremes the " Washington " value is the lower. For a given dry-bulb temperature the maximum difference occurs at 50 per cent. relative humidity where, for a total pressure of 1000 mb., it is ½ per cent. at 64°F. and 2 per cent. at 107°F. The grounds for changing the definition have not been made clear and have not been considered strong enough to justify a change in Meteorological Office procedure. As in previous designs therefore, the new slide-rule provides for the determination of relative humidity as the percentage ratio of the actual vapour pressure to the saturation vapour pressure at dry-bulb temperature.

Computation of dew point from psychrometric data.—The basis of computation is the simplified Regnault formula adopted by the Meteorological Office

$$x = f - A\frac{p}{p_0}(t - t') \qquad \text{.. (1)}$$

where t = dry-bulb temperature, t' = wet-bulb temperature, in degrees Fahrenheit.

p = pressure at time of observation in millibars.

p_0 = standard pressure (1000 mb.) to which the value of A applies.

A = the psychrometric constant, the value of which depends upon the speed of air flow over the thermometers and upon whether the wet bulb is covered with water or ice.

f = the saturation pressure at the temperature of the wet-bulb, in millibars.

x = the vapour pressure at the time of observation, in millibars.

It is assumed that at temperatures of 32°F. or below the wet bulb becomes an ice bulb; in these circumstances f is the saturation pressure with respect to ice at temperature t'.

The dew point is the temperature for which x is the saturation pressure with respect to water, at all temperatures.

Following the practice of "Hygrometric Tables"* the values of the constant A for a pressure of 1000 mb. are

	Wet bulb	Ice bulb
For thermometers in standard screens without artificial aspiration	0·444	0·400
For aspirated thermometers (Assmann psychrometer, aircraft thermometers, whirling psychrometers)	0·37	0·33

Surface observations.—Except when the temperature and humidity are extremely low small variations in the quantity Ap/p_0 do not substantially affect the computed value of x. It is therefore normal practice to ignore variations from unity in the factor p/p_0 in the case of stations not more than about 3,000 ft. above sea level. For land stations below this level, and ship stations, equation (1) therefore takes the simple form

$$x = f - A(t - t') \qquad \text{.. (2)}$$

If now we write

$a_w(t)$ = saturation pressure with respect to water at any temperature t

$a_i(t)$ = saturation pressure with respect to ice at any temperature t

t_d = dew point

we have $x = a_w(t_d)$ at all temperatures

$f = a_w(t')$ for $t' > 32$°F.

$f = a_i(t')$ for $t' \leqslant 32$°F.

and equation (2) takes the following forms.

---

*London, Meteorological Office. Hygrometric Tables. 4th edn., London, 1940.

'(i) Thermometers in standard screens

Wet bulb above freezing point

$$a_w(t_d) = a_w(t') - 0{\cdot}444\ (t - t') \quad \cdot\cdot \quad (3)$$

Wet bulb at or below freezing point

$$a_w(t_d) = a_i(t') - 0{\cdot}400\ (t - t') \quad \cdot\cdot \quad (4)$$

(ii) Aspirated thermometers

Wet bulb above freezing point

$$a_w(t_d) = a_w(t') - 0{\cdot}37\ (t - t') \quad \cdot\cdot \quad (5)$$

Wet bulb at or below freezing point

$$a_w(t_d) = a_i(t') - 0{\cdot}33\ (t - t') \quad \cdot\cdot \quad (6)$$

The four equations (3) to (6) are the bases of computation of dew point from dry-bulb and wet-bulb temperatures under the four sets of conditions postulated.

To solve any of these equations (say equation (3)) mechanically we need, to start with, a temperature scale so divided that the distance from an arbitrary zero to the division marked t is proportional to $a_w(t)$. Call this distance $B.a_w\ (t)$, B being the length corresponding to one millibar on the scale. If now we start at the point on the scale marked t' and move backward a distance $0{\cdot}444\ B(t - t')$ we see from equation (3) that we arrive at a point whose distance from the zero is $B.a_w(t_d)$, that is to say we arrive at the dew point.

Turning now to the actual slide-rule the scale of $a_w(t)$ is scale (1), and the operation of subtracting the quantity $0{\cdot}444\ (t - t')$ is performed with the aid of scale (2) which is so divided that the length of one degree is equal to 0·444 times the length corresponding to one millibar on scale (1).

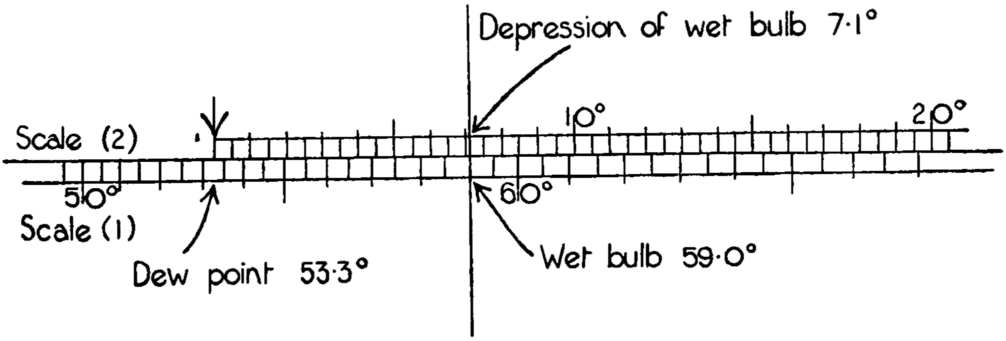


FIG. 2—COMPUTATION OF DEW POINT; WET-BULB READING ABOVE FREEZING POINT
Thermometers in screen

To deal with aspirated thermometer readings (equation (5)) we require a different " depression " scale, *i.e.* one in which the length of one degree is 0·37 times the length corresponding to one millibar on scale (1). This is scale (2B), which is coloured red to distinguish it readily from scale (2).

For ice-bulb readings (equations (4) and (6)) the procedure is slightly more complicated, because we need two saturation vapour-pressure scales, one with respect to supercooled water and the other with respect to ice, both graduated from the same arbitrary zero. Taking equation (4), we start from the point t' on the ice-saturation scale (1B) and step back a distance corresponding to $0{\cdot}400\ (t - t')$ on the depression scale (2A). This, if read on scale (1B) would give the hoar-frost point, but as we require the dew point the setting is transferred to the water-saturation scale (1A) placed immediately below it. The corresponding depression scale for an aspirated ice bulb is (2C). In order to cope with low temperatures where the change of saturation vapour pressure per degree of temperature is very small, the scale equivalent of one millibar in scales (1A) and (1B) is much greater than in scale (1) and the depression scales (2A) and (2C) are of course expanded proportionately.

The working instructions for the determination of dew point are thus as follows

(i) Thermometers in screen. Wet bulb not frozen (Fig. 2)

Set cursor over wet-bulb reading on (1)
Move slide to bring depression of wet bulb on (2) under cursor
Read DEW POINT on (1) under zero index of (2).

(ii) Thermometers in screen. Wet bulb frozen (ice-bulb) (Fig. 3)

Set cursor over ice-bulb reading on (1B)
Move slide to bring depression of ice bulb on (2A) under cursor
Set cursor over zero index of (2A) and read DEW POINT on (1A)

(iii) Aspirated psychrometer. Proceed as in (i) and (ii) but use RED scales (2B) instead of (2) and (2C) instead of (2A).

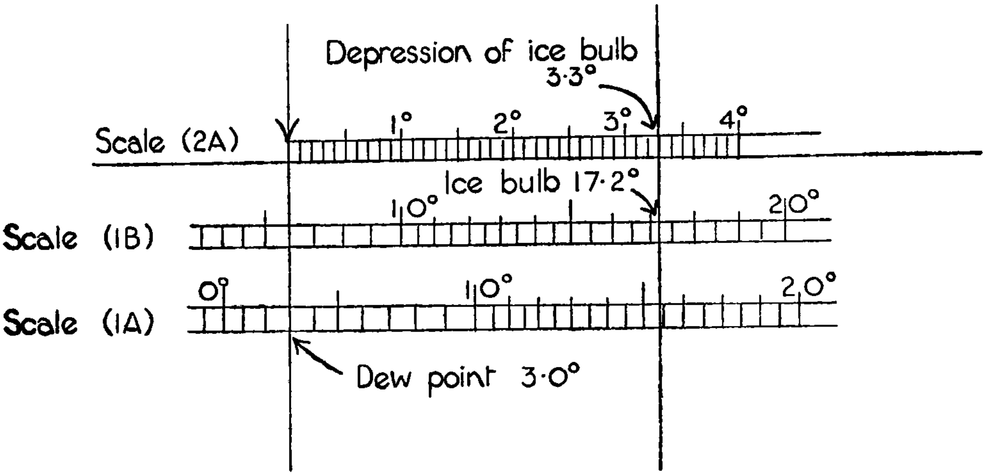


FIG. 3—COMPUTATION OF DEW POINT; WET-BULB READING BELOW FREEZING POINT (ICE BULB)
Thermometers in screen

Aircraft observations.—Readings on aircraft flying at low levels (*e.g.* on the low-level legs of meteorological reconnaissance flights) are dealt with in the same way as for aspirated psychrometers. For higher levels the "adjusted" depression of wet bulb $p(t - t')/1{,}000$ must first be evaluated, using scales (4) and (5) on the upper part of the rule. These are ordinary logarithmic scales. Set 1,000 on scale (5) against the observed depression on scale (4). Set the cursor over p (the pressure at the level of observation) on scale (4) and read the adjusted depression under the cursor on scale (5). If the depression is very small, *e.g.* 2·0°F. or less, multiply by 10 first and then divide the answer by 10. The procedure is then exactly the same as for an aspirated psychrometer, the adjusted depression being used instead of the actual depression.

High-level observations with un-aspirated thermometers.—First obtain the adjusted depression, being careful to note that p is the pressure corrected to station level. Then proceed as described above for thermometers in screens, using the adjusted depression in place of the actual depression.

For insertion in synoptic messages it suffices to read the dew point to the nearest whole degree. When, however, the dew point is required as the first step in the computation of other parameters it is advisable to note the value to the nearest tenth of a degree, and the scales are sufficiently open for this to be practicable in most cases.

Computation of vapour pressure and relative humidity. Scale (3) on the upper edges of the slide is a temperature scale in which the argument is the logarithm of the saturation vapour pressure over water. If the slide is adjusted so that the index marked R.H. reads 100 on the two-cycle logarithmic scale (4) then the reading on (4) opposite any temperature graduation on (3) is the saturation vapour pressure in millibars for that temperature. Consequently with the R.H. index set to 100 the vapour pressure x is at once obtained on scale (4) by setting the cursor over the dew point on (3). Leaving the cursor so set, if the dry-bulb temperature on (3) is brought under the cursor by moving the slide, the R.H. index now indicates the relative humidity on scale (4).

The procedure of the previous paragraph is applicable when the dew point is above 20°F. For lower temperature ranges scale (3A) is used in place of scale (3). The basis of graduation of scale (3A) is the same as in scale (3) but its zero is displaced 5 in. to the right, so that when the R.H. index reads 100 and the cursor is placed over any graduation on scale (3A), the reading on scale (4) under the cursor is ten times the saturation vapour pressure in millibars for that temperature. The indicated value of x read on (4) when the cursor is set over the dew point on (3A) must therefore be divided by ten. The indicated value of the relative humidity is however correct as it stands, provided the dry-bulb setting is also made on scale (3A).

It occasionally happens that a dew point below 20° occurs with a dry bulb above the upper limit of scale (3A), *i.e.* 45°F. In such a case the procedure is as follows : using scale (3A), evaluate the vapour pressure, remembering to divide the indicated value by ten. Set the cursor over the (true) vapour pressure on scale (4) and bring the dry-bulb reading on scale (3) under the cursor; read the relative humidity against the R.H. index on scale (4).

Computation of mixing ratio, specific humidity and vapour density.—When the vapour pressure x has been computed the mixing ratio r given by the formula

$$r = 0{\cdot}62197 \frac{x}{p - x}$$

can readily be evaluated, using scales (4) and (5). The position of the constant multiplier is shown on scale (5) by an index lettered M.R. Set the cursor over the value of x on scale (4); bring the value of $(p - x)$ on scale (5) under the cursor and read the value of r on scale (4) against the index M.R. For low values of x multiply by 10 in the numerator only before computing and then divide the answer by 10. The value of r is in grams per kilogram.

The specific humidity (q) is given by

$$q = 0{\cdot}62197 \frac{x}{p}$$

and is calculated in the same way, the only difference being the substitution of p for $(p - x)$ in the division. As x is always small compared with p the two quantities rarely differ by more than two or three per cent.

The vapour density (d_v) is given by

$$d_v = 216{\cdot}7 \frac{x}{T}$$

where T is the temperature on the absolute scale. A special scale (6) is provided on the back of the slide for computing this parameter. Set the cursor over the value of x on scale (4) and bring the value of the dry-bulb temperature on scale (6) under the cursor; read the value of d_v on scale (4) in grams per cubic metre, against the index marked V.D.

Radio-sonde observations.—Radio-sondes include devices for determining the pressure, temperature and relative humidity at various levels in the free atmosphere. The humidity element is operated by a hygrometric material (gold-beater's skin in the British version) the dimensions of which respond to variations in the relative humidity, and it has been established that at temperatures below freezing point the controlling factor is the relative humidity with respect to supercooled water. Values of vapour pressure and dew point can therefore be readily derived from radio-sonde observations of temperature and relative humidity by making use of scales (3), (3A) and (4).

Set the R.H. index to the observed value of the relative humidity on scale (4). If the temperature (t) is above 45° set the cursor over t on scale (3) and read the vapour pressure (if wanted) on scale (4). Leaving the cursor in this position set the R.H. index to 100 on scale (4). The dew point is then read under the cursor line.

For values of t below 45° use scale (3A) instead of scale (3). The indicated vapour pressure has in this case to be divided by 10, but the dew point is correctly shown on scale (3A).

As scale (3) does not read below 20° the procedure described above will not work when t is above 45° and the relative humidity is less than about 40 per cent. Unless the relative humidity is less than 10 per cent. it will however be possible to read the vapour pressure on scale (4). The dew point can then be evaluated by the following artifice. Multiply the vapour pressure by 10 and set the cursor over the value on scale (4). Leaving the cursor in this position set the R.H. index to 100 and read the dew point under the cursor on scale (3A). If the relative humidity is less than 10 per cent. proceed as follows. First set the R.H. index to ten times the observed relative humidity on scale (4). Set the cursor over t on scale (3), read the vapour pressure on scale (4) and divide by 10 to obtain the true vapour pressure (if wanted). Leaving the cursor in this position, set the R.H. index to 100 and read the dew point on scale (3A).

Conversion of hoar-frost point to dew point.—The Dobson-Brewer frost-point hygrometer provides an accurate means of measuring the hoar-frost point directly on an aircraft. To convert the reading to dew point set the cursor over the hoar-frost point reading on scale (1B) and read the dew point under the cursor on scale (1A). Having obtained the dew point any other parameter may be computed by the procedures described on p. 71.

Standard saturation vapour pressures.—The standard Goff-Gratch values of saturation vapour pressure may be obtained by estimation to two or three significant figures by the following procedures.

Saturation with respect to water

Range 20° to 110°F. Set the R.H. index to 100 on scale (4) and place the cursor over the temperature on scale (3). Read the saturation vapour pressure on scale (4) under the cursor.

Range —50° to 20°F. With R.H. index set to 100, set cursor over the temperature on scale (3A). Read scale (4) and divide by 10.

Range —60° to —50°F. Set cursor over the temperature on the dew-point scale on back of stock and read the saturation vapour pressure under the cursor on scale (7).

Saturation with respect to ice

Range 22° to 32°F. Set cursor over temperature on scale (1B) and read dew point on scale (1A). With R.H. index set to 100 on (4), set cursor over dew point on scale (3) and read saturation vapour pressure under the cursor on scale (4).

Range —20° to 22°F. Same procedure as above but set cursor over dew point on scale (3A), read on scale (4) and divide by 10.

Range —130° to —20°F. Set cursor over the temperature on the frost-point scale on back of stock and read the saturation vapour pressure under the cursor on scale (7).

Miscellaneous hygrometric computations.—Most hygrometric computations involve either the inter-conversion of parameters or the determination of changes of relative humidity resulting from changes of temperature or moisture content at constant pressure.

A quantity frequently required in evaporation problems is the saturation deficit. This parameter, expressed in millibars, is obtained by subtracting the vapour pressure from the saturation vapour pressure at the temperature of observation.

Example. Air at 70°F., relative humidity 75 per cent., determine the saturation deficit in millibars. Set R.H. index to 25 (= 100 — relative humidity) on scale (4). Set cursor over 70° on scale (3) and read the saturation deficit under the cursor on scale (4). Answer 6·3 mb. Use scale (3A) if the temperature is below 45° and divide the answer by 10.

If the saturation deficit is required in grams per cubic metre it is necessary first to determine the vapour density by the use of scale (6) (see p. 72), giving the answer 13·8 gm./m.^{3} Next determine the saturation vapour density by the following method. Set the R.H. index to 100 and set the cursor over the temperature (70°F.) on scale (3). Without moving the cursor bring temperature 70°F. on scale (6) under the cursor. Read the saturation vapour density (18·5) on scale (4) opposite the vapour-density index. The saturation deficit is then equal to 18·5 — 13·8 = 4·7 gm./m.^{3}

The following example illustrates a typical application to problems in which constancy of vapour pressure may be assumed.

Example. Air at 45°F., relative humidity 90 per cent., is warmed to a temperature t°F. without adding or removing water, determine the new value of the relative humidity for various values of t. Set R.H. index to 90 and place cursor over 45°F. on scale (3). This gives the vapour pressure 9·2 mb. on scale (4) which is unaltered during the warming. Bring any desired value of t on scale (3) under the cursor and the R.H. index will then show the corresponding value of the relative humidity, *e.g.* t = 50°, relative humidity = 75 per cent.; $t = 60°$, relative humidity = 52 per cent.; $t = 65°$, relative humidity = 43·5 per cent.

Acknowledgements.—The detailed specification and drawings for the Mk. III humidity slide-rule were prepared in the General Instruments Branch of the Meteorological Office under the direction of Mr. O. M. Ashford from a sketch design provided by the author. The onerous task of carrying out the computations for specifying the exact positions of all scale divisions was performed by Mr. R. H. Collingbourne.

ELEMENTS OF ANOMALOUS RADIO PROPAGATION

By E. KNIGHTING, B.Sc.

The distance of the optical horizon of an observer at height h is $\sqrt{(2ha)}$ where a is the radius of the earth, and it might be expected that the range of an electromagnetic wave propagated at height h would approximately have the same range. In the case of large wave-lengths, *i.e.* radio waves of the order of hundreds of metres it is known that, owing to reflections at various layers (Kennelly-Heaviside, Appleton layers), the range is very much extended. However, with a directed energy beam, which does not suffer reflection at these layers owing to the small angle of propagation, the range might be expected to approximate to $\sqrt{(2ha)}$. There is a diffraction zone below the horizon which might account for small increases in the range.

The practical use of radar showed that ranges very much greater than $\sqrt{(2ha)}$ were encountered. For example English coastal radars reported observations of the European coast, well beyond the optical horizon, and at Bombay a 1½ m. radar at a height of 255 ft. and an optical horizon of about 25 miles observed shipping up to ranges of 500 miles and occasionally more. It is the explanation of the possibility of such large ranges that we are concerned with in the following paragraphs.

The refractive index of the atmosphere.—The path of an electromagnetic wave depends upon the dielectric properties of the medium. The dielectric constant of water vapour is given experimentally[1]*† by

$$\epsilon - 1 = 180 \times 10^{-6}\left(1 + \frac{5580}{T}\right)\frac{p}{T}$$

where T is the absolute temperature and p the pressure of water vapour in millimetres of mercury.

The dielectric constant for dry air is given experimentally by

$$\epsilon - 1 = 210 \times \frac{P}{T} \times 10^{-6}$$

where P is the pressure of the air, and, since dielectric constants are additive, the dielectric constant for moist air is

$$\epsilon - 1 = \left\{210\frac{P}{T} + 180\left(1 + \frac{5580}{T}\right)\frac{p}{T}\right\} \times 10^{-6}$$

where P, p are the partial pressures of dry air and water vapour. Since the refractive index n is given by $n = \sqrt{\epsilon}$, the refractive index of moist air is given with sufficient accuracy by

$$n - 1 = \frac{79}{T}\left\{P - \frac{e}{7} + \frac{4800e}{T}\right\} \times 10^{-6}$$

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*The index numbers refer to the list of references on p. 81.

†Results of many workers.

where P is now the total pressure, e the vapour pressure in millibars and T the absolute temperature.

A rough calculation, taking $T \triangleq 300°$A., $P \triangleq 1000$ mb., $e \triangleq 10$ mb. shows that $(n - 1)$ is of the order 300×10^{-6} in the atmosphere. For ease of calculation a new unit m is introduced, given by

$$m = (n - 1) \times 10^6 = \frac{79}{T}\left\{P - \frac{e}{7} + \frac{4800e}{T}\right\}$$

and the new unit is known as an M-unit, being measured in millionths.

In the atmosphere there is a general lapse of m, the mean lapse being $1{\cdot}3M/100$ ft., and an atmosphere with such a lapse is often termed a standard atmosphere.[2]†

Ray curvature and modified refractive index.—From the principle of least time it is easily shown that in " flat earth " co-ordinates, where h is the height above the earth's surface, x the horizontal distance, n the refractive index and a the earth's radius, the differential equation of the ray path is

$$0 = \frac{d^2h}{dx} - \left\{\frac{1}{n}\cdot\frac{dn}{dh} + \frac{2}{a+h}\right\}\left(\frac{dh}{dx}\right)^2 - \left\{\frac{1}{n}\cdot\frac{dn}{dh}\left(1 + \frac{h}{a}\right) + \frac{1}{a}\right\}\left(1 + \frac{h}{a}\right)$$

In many radar problems, particularly in long-range detection problems, dh/dx, which is the inclination of the ray to the horizon, is small and the second term can be neglected. The multiplying factor $(1 + h/a)$ in the third term is little different from unity near the earth's surface.

As we have seen above, n only varies by 300 parts in a million and may be taken as unity.

The equation then reduces to

$$\frac{d^2h}{dx^2} - \left(\frac{dn}{dh} + \frac{1}{a}\right) = 0 \qquad .. (1)$$

The ray curvature is simply $-d^2h/dx^2$ with dh/dx small, and hence referred to a flat earth the ray curvature K is

$$K = -\left(\frac{dn}{dh} + \frac{1}{a}\right) \qquad .. (2)$$

and the absolute curvature is, taking into account the earth's curvature,

$$K' = -\frac{dn}{dh} \qquad .. (3)$$

We can look at equation (2) in a slightly different way, for the curvature referred to the earth is that produced by a refractive index $(n + h/a)$. We define, therefore, a modified refractive index

$$M' = \left(n + \frac{h}{a} - 1\right) \times 10^{-6}$$

in M-units. It is this modified refractive index that is used in practical radio meteorological work.

Again returning to (2), if dn/dh is constant, if we put

$$\frac{1}{ka} = \frac{dn}{dh} + \frac{1}{a}$$

then the ray curvature with respect to an earth of radius ka is zero and the ray can be drawn as a straight line. For the value dn/dh quoted then $adn/dh \triangleq -\frac{1}{4}$ and the straight-line rays are drawn on an earth of radius $4a/3$. ka is termed the equivalent earth radius, and varies from place to place with the lapse rate of n (assumed constant). Fig. 1 shows rays referred to the earth, the equivalent earth and the flat earth.

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†A standard atmosphere has not been agreed[2].

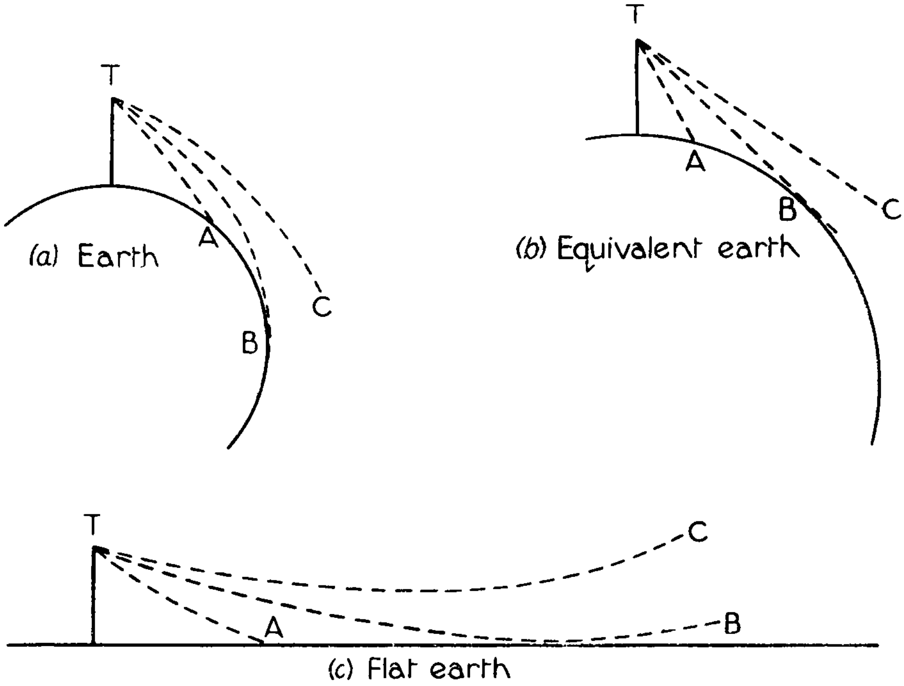


FIG. 1—REPRESENTATION OF RAYS ON (*a*) EARTH (*b*) EQUIVALENT EARTH (*c*) FLAT EARTH

TA is ray within horizon, TB is horizon ray, TC does not reach earth

Lapse rate of refractive index.—We see that the variation of refractive index of the atmosphere with height is an important factor in refracting electro-magnetic energy. From (2) if $dn/dh + 1/a < 0$ then the ray is bent towards the earth. In terms of the modified refractive index M', the ray is bent towards the earth if there is an M' lapse. We may express this in terms of meteorological variables through the equation

$$M' - \frac{h}{a} = m = 10^6\,(n-1) = \frac{79}{T}\left\{p - \frac{e}{7} + \frac{4800e}{T}\right\}$$

first remarking that the term $e/7$ is small compared with the other terms.

Pressure effect.—

$$\left(\frac{dm}{dh}\right)_{T,e} = \frac{79}{T}\,\frac{\partial P}{\partial h}$$

and since $\partial P/\partial h = -g\rho$, near the surface this is a constant contribution, approximately $1M/100$ ft.

Temperature effect.—

$$\left(\frac{dm}{dh}\right)_{P,e} = -\frac{79}{T^2}\left\{P + \frac{9600e}{T}\right\}\frac{\partial T}{\partial h}$$

The temperature effect thus depends on P and the moisture content. An estimate of $(dm/dh)_{P,e}$ for $T = 288$°A., $P = 1000$ mb., $e = 10$ mb. is

$$\left(\frac{dm}{dh}\right)_{Pe} \doteq -1{\cdot}25\,\frac{\partial T}{\partial h}$$

For bending a ray towards the earth (earth's radius $= 6{\cdot}4 \times 10^6$ m.)

$$1{\cdot}25\,\frac{\partial T}{\partial h} > \frac{1}{6{\cdot}4} \text{ or } \frac{\partial T}{\partial h} > \frac{1}{8}\,°\text{C./m.}$$

which is equivalent to 7°F./100 ft. Thus an inversion of 7°F. per 100 ft. is capable of bending the ray down towards the earth.

Humidity effect

$$\left(\frac{dm}{dh}\right)_{P,T}=\frac{79}{T}\times\frac{4800}{T}.\frac{\partial e}{\partial h}$$

We express the humidity in terms of a mixing ratio q grams of water vapour per kilogramme of dry air, and at 288°A. find that a lapse rate of mixing ratio greater than 2/3 gm./Kg./100 ft. is necessary to produce downard bending of the rays. If we denote by α and β the critical values for temperature and humidity gradients obtained above and by T', q' the temperature and humidity gradients, then the combined effect necessary for downward ray bending is $T'/\alpha+q'/\beta>1$ or in the cases considered:—

$$\frac{\text{Temperature gradient (per 100 ft.)}}{7}+\frac{\text{Humidity lapse (per 100 ft.)}}{2/3}>1$$

In the rest of the paper, the units used will be degrees Fahrenheit and feet.

Observations of gradients exceeding critical values.—The necessary gradients for bending rays towards the earth as found above are large and we must inquire whether such gradients have in actual fact been found.

Temperature inversions over land.—The experiments carried out at Porton and Leafield[3,4] provide a study of the vertical gradient of temperature in the first hundred metres or so and show that the required gradient is exceeded in about 10 per cent. of cases near the ground. Experiments made at Rye measuring temperature and humidity at 4, 50, 155 and 355 ft. have been analysed. These show that the critical temperature inversion of 7°F./100 ft. is exceeded on about 10 per cent. of all occasions in the layer 4 to 50 ft. and on less than 5 per cent. of all occasions in the layer 50 to 155 ft.

Inversions over the sea.—Experiments have been made in Cardigan Bay and the Irish Sea by means of ships using thermocouples attached to booms and to balloon cables to observe temperature and humidity. In the same series of experiments low-flying aircraft also made observations. A preliminary analysis of a series of results showed that in a few cases inversions satisfying the criterion were observed. Inversions will be more rare over the sea than over land from general considerations, if we exclude the first 10 ft. or so where there are marked variations.

Humidity lapses over the land.—The analysis of the Rye records shows that the critical lapse rate of humidity is exceeded on about 30 per cent. of all occasions in the layer 4 to 50 ft., and on about 10 per cent. of all occasions in the layer 50 to 155 ft.

Humidity lapses over the sea.—Humidity measurements have been made in the lower layers over the sea by low-flying aircraft and also from ships, using balloons with psychrometers attached to the cables. Care must be taken in comparing the results obtained by these two methods, since the aircraft measures a mean humidity over a horizontal distance, while the ship measurements are of humidity ***in situ***. It is found that the humidity lapse rate over the sea often exceeds the critical lapse rate.

Modified refractive index curves and ray tracing.—The modified refractive index (M.R.I.) is, from p. 75

$$M' = \left(n + \frac{h}{a} - 1\right) \times 10^6$$

and from the approximate ray equation

$$\frac{d^2h}{dx^2} = \frac{dM'}{dh} \times 10^{-6}.$$

Integrating this equation, with suffix $_0$ denoting values at the surface

$$\left(\frac{dh}{dx}\right)^2 - \left(\frac{dh}{dx}\right)_0^2 = 2 \times 10^{-6}\,(M' - M_0') \qquad \ldots\ (4)$$

Remembering that dh/dx is the slope of the ray, then if $dh/dx = 0$, the ray is parallel to the earth and

$$-\left(\frac{dh}{dx}\right)_0^2 = 2 \times 10^{-6}\,(M' - M_0')$$

For a real solution $M_0' > M'$ and the maximum value of $(dh/dx)_0$ is given by the minimum value of M', say $\overline{M}'$. Denoting this maximum angle by α_0 then

$$\alpha_0^2 = 2 \times 10^{-6}\,(M_0' - \overline{M}')$$

and only those rays emerging at an angle less than α_0 from the transmitter will be bent so that they are at least parallel to the earth. It should be noted that M' is dominated above a certain height by the term h/a and the M' curve will generally slope to the right, with a slope $1/a$ above this height.

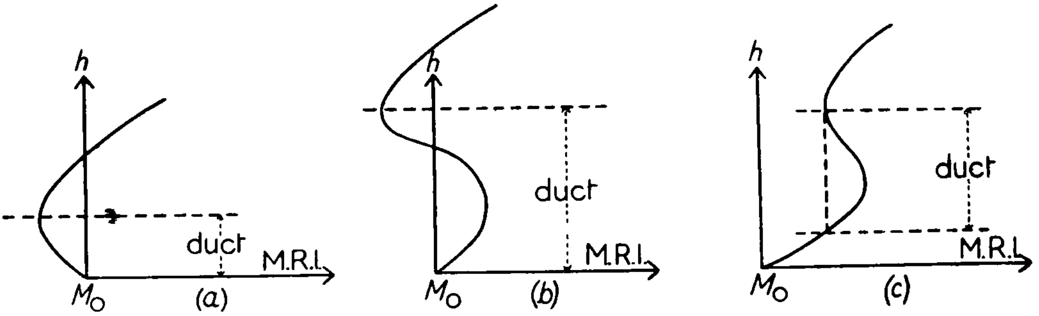


FIG. 2—THREE DIFFERENT TYPES OF M.R.I. CURVES AND ASSOCIATED DUCTS

Errata:—for " $M_{\circ}$ " *read* " $M_{\circ}'$ "

The M.R.I. curves of greatest interest to the radio meteorologist are those which have a negative slope for some height interval. There are three main types as in Fig. 2 :

(i) M.R.I. lapse from the surface to a certain height after which the M.R.I. increases with height, having an asymptotic slope $1/a$.

(ii) M.R.I. increases with height, then decreases over a range to a value less than the surface value, and then increases again with height. Asymptotic slope $1/a$.

(iii) M.R.I. increases with height, then decreases over a range to a value greater than the surface value and then increases again with height as in (ii).

Using equation (4) we can trace the rays emerging from the transmitter at different angles. Perfect reflection at the lower surface is assumed, although over land this is only very approximate.

Consider an M.R.I. as in Fig. 3 with rays emerging at ground level, and a ray emerging from the transmitter at angle α_1 with the horizontal. Providing α_1 is less than α_0, where

$$\alpha_0^2 = 2\,(M_0' - \overline{M'}) \times 10^{-6},$$

then the ray will be bent parallel to the earth at some level where the M.R.I. is M given by

$$\alpha_1^2 = 2\,(M_0' - M) \times 10^{-6},$$

since the angle α the ray makes with the horizon is given by

$$\alpha^2 - \alpha_1^2 = 2\,(M' - M_0') \times 10^{-6}.$$

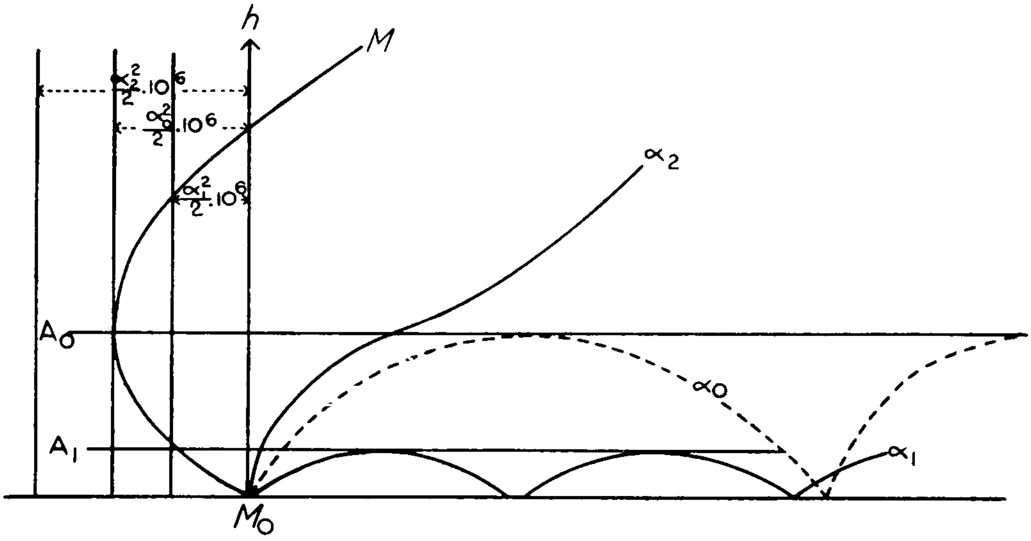

h
M
$\frac{\alpha_2^2}{2}.10^6$
$\frac{\alpha_0^2}{2}.10^6$
$\frac{\alpha_1^2}{2}.10^6$
α_2
A_0
α_0
A_1
α_1
M_0

FIG. 3—RAYS EMERGING AT GROUND LEVEL

Errata:—for “M_0” *read* “M_0'” *and for* “M” *read* “M'”

The ray emerging at angle α_1, becomes parallel to the earth at height A_1, and subsequently its motion is governed by reflection at the surface and bending in the layer A_1 to the surface. The ray emerging at the angle α_0 is similarly bent down towards the earth, being parallel to the earth at height A_0, its subsequent path being similar to that of α_1. The ray emerging at angle α_2 is bent towards the earth, but at height A_0 is not sufficiently bent to be parallel to the earth's surface ; thereafter it is bent away from the earth, since dM'/dh is positive. Thus all the rays emerging from the transmitter at an angle α_0 or less are trapped in a region below A_0 and move around the earth's surface. All the rays emerging at an angle greater than α_0 are not trapped in this manner. The region below A_0 is called a duct and the height to A_0 termed the duct width.

We can easily establish the duct property in the case represented in Fig. 2(*b*) by similar tracing. The case of Fig. 2(*c*) needs a little care. With the transmitter in the duct the ray-tracing diagram is given by Fig. 4.

The ray emerging at angle α_1, from the transmitter T, where the M.R.I. is M'_0 becomes parallel to the earth's surface at height L_1, is bent down towards the earth in the region where the M.R.I. gradient is negative, and upwards where the M.R.I. gradient is positive until at level L_1', it is again parallel to the earth's surface, its subsequent path being as shown. A ray emerging downwards, at angle α_1, is similarly trapped in the layer L_1L_1'. The ray emerging at angle α_0 is similarly trapped in the region L_0L_0'. The ray emerging at angle α_2

greater than α_0 is not sufficiently bent to be trapped and so is not kept in the confines of the duct. Such a downward ray, reflected at the earth's surface is shown in the diagram by α_2.

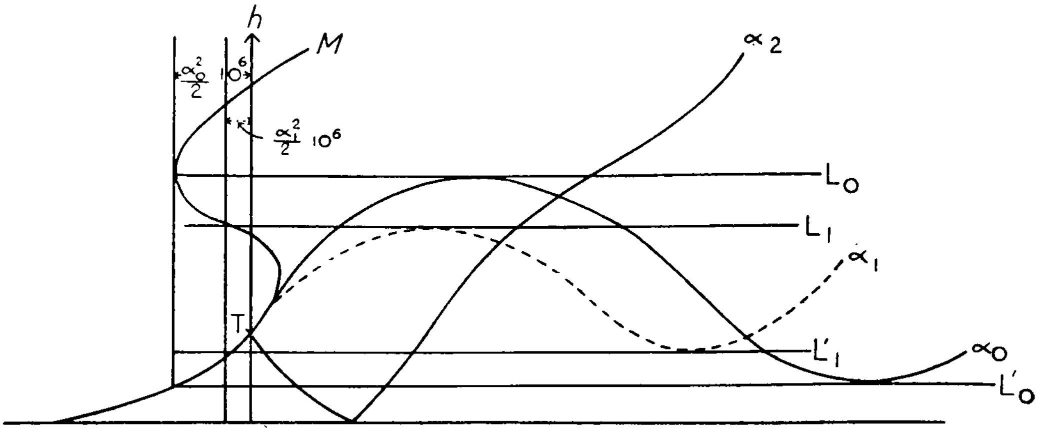
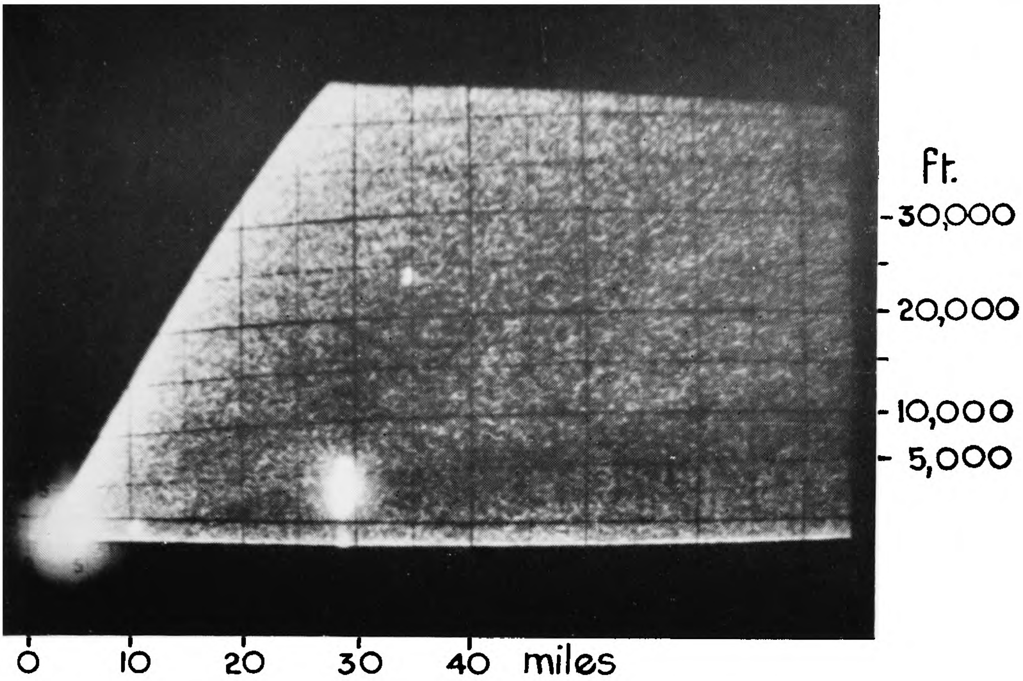


FIG. 4—TRANSMITTER IN THE DUCT
Errata:—for "M" read "M′"

The ray theory outlined above is capable of explaining why electro-magnetic energy is propagated far beyond the normal range. All energy emitted at an angle less than the maximum angle α_0 is trapped and continues around the earth's surface, suffering attenuation until it is too weak to be detected. The energy can be reflected by a target and returned to the source to be detected by a radar unit. The maximum angle α_0 is, of course, very small ; for $M' - \overline{M'} = 8M$-units the maximum angle is only $\pm\frac{1}{4}^\circ$ with the pole of the beam. Thus trapping only occurs usually in about $\frac{1}{2}^\circ$ elevations. When rays are trapped a condition of super-refraction is said to exist.

Limitations of the theory.—Although the theory successfully explains why electro-magnetic energy is observed at great distances it fails to draw any distinction between the behaviour of waves of different frequency. The attenuation varies with frequency, but the variation is not sufficient to account for the fact that super-refraction is only observed between about 30 and 30,000 megacycles per second. It also fails to explain why there is a noticeable difference in the super-refractive effects in this range, super-refraction increasing with frequency. Lastly the theory fails to predict field strengths under various conditions, although by ray tracing some estimate of field strength can be made.

Application of wave theory.—The limitations noted above can be removed by application of the electro-magnetic wave theory[5]. Shorn of the technical mathematics the process is to resolve the electro-magnetic wave into components or modes much as a function may be expanded into a Fourier series. It is found that each mode has a characteristic track width inside which most of the energy is confined, although there is some leakage of energy from the track width. The track width for any mode is a function of the dielectric properties of the medium through which the wave is moving and hence a function of the meteorological variables. The effect of a duct is to suppress the leakage from those modes whose track widths lie inside it and to partially guide those modes whose track widths are slightly in excess of the duct width. Consider only the first mode, and denote it by $H_1(\lambda)$ to indicate that it refers to a wave-length λ, and let it have a track width $w_1(\lambda)$. It can be shown that the track width is a function of wave-length, in addition to being a function of the meteorological


Ft.
-30,000
-20,000
-10,000
-5,000
0
10
20
30
40 miles

RADAR ECHO FROM A COLUMN OF SMOKE
Observed on a height-range indicator, East Hill, 1400 G.M.T., August 18, 1949 (see p. 89)

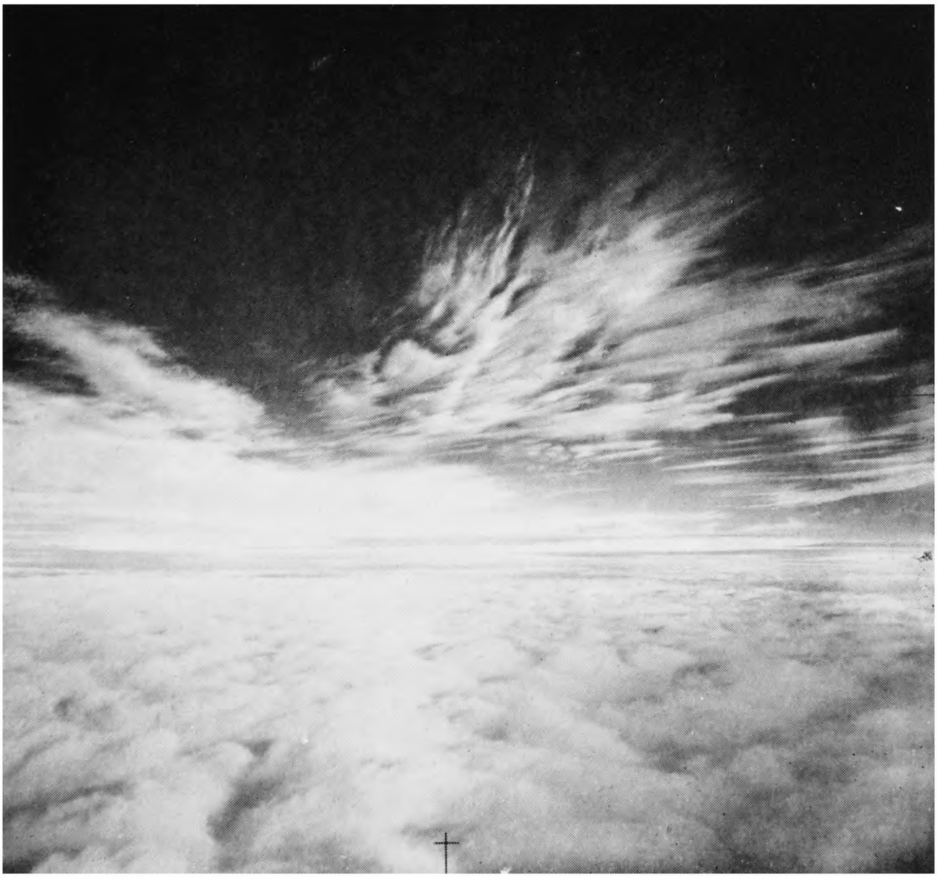
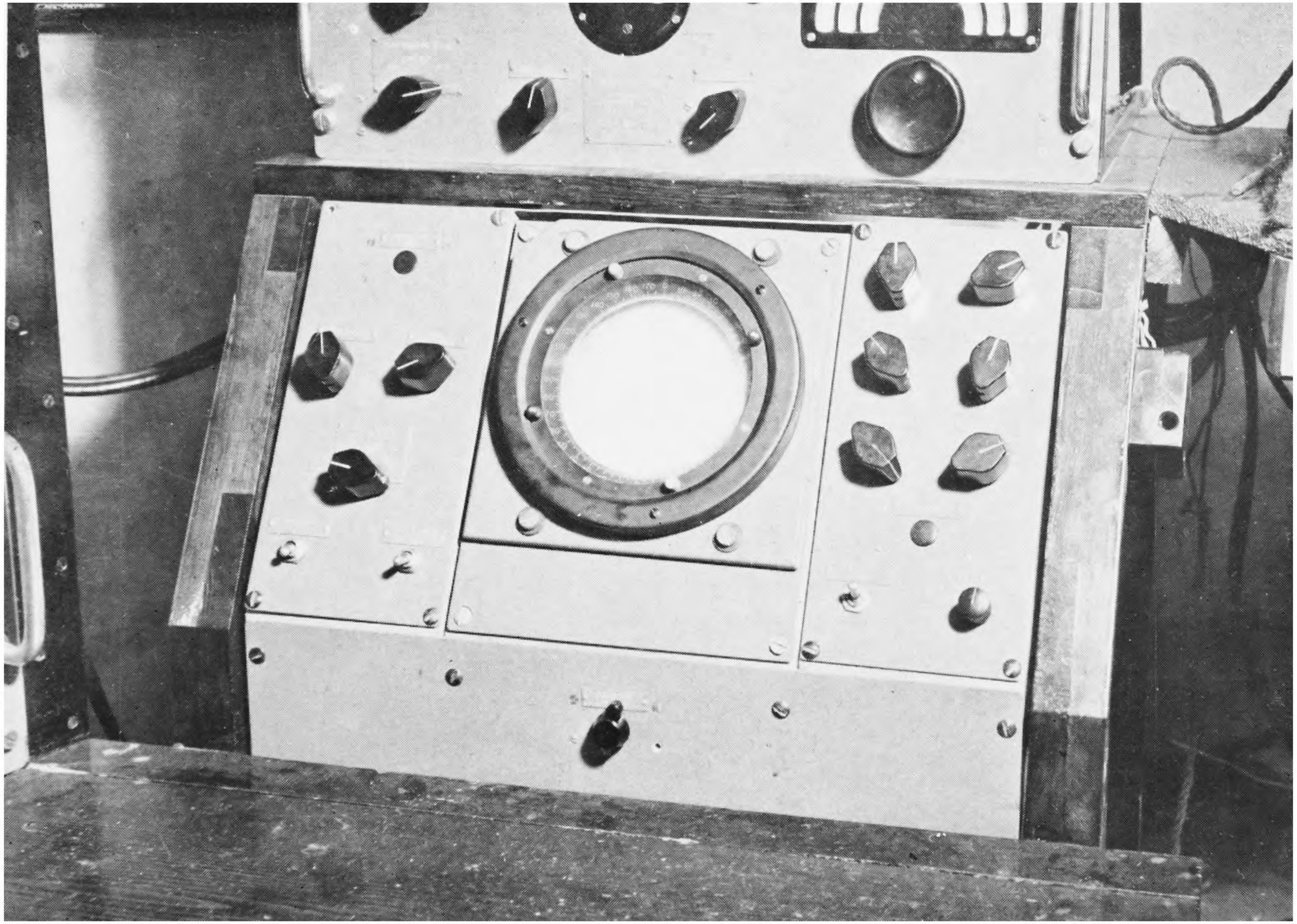


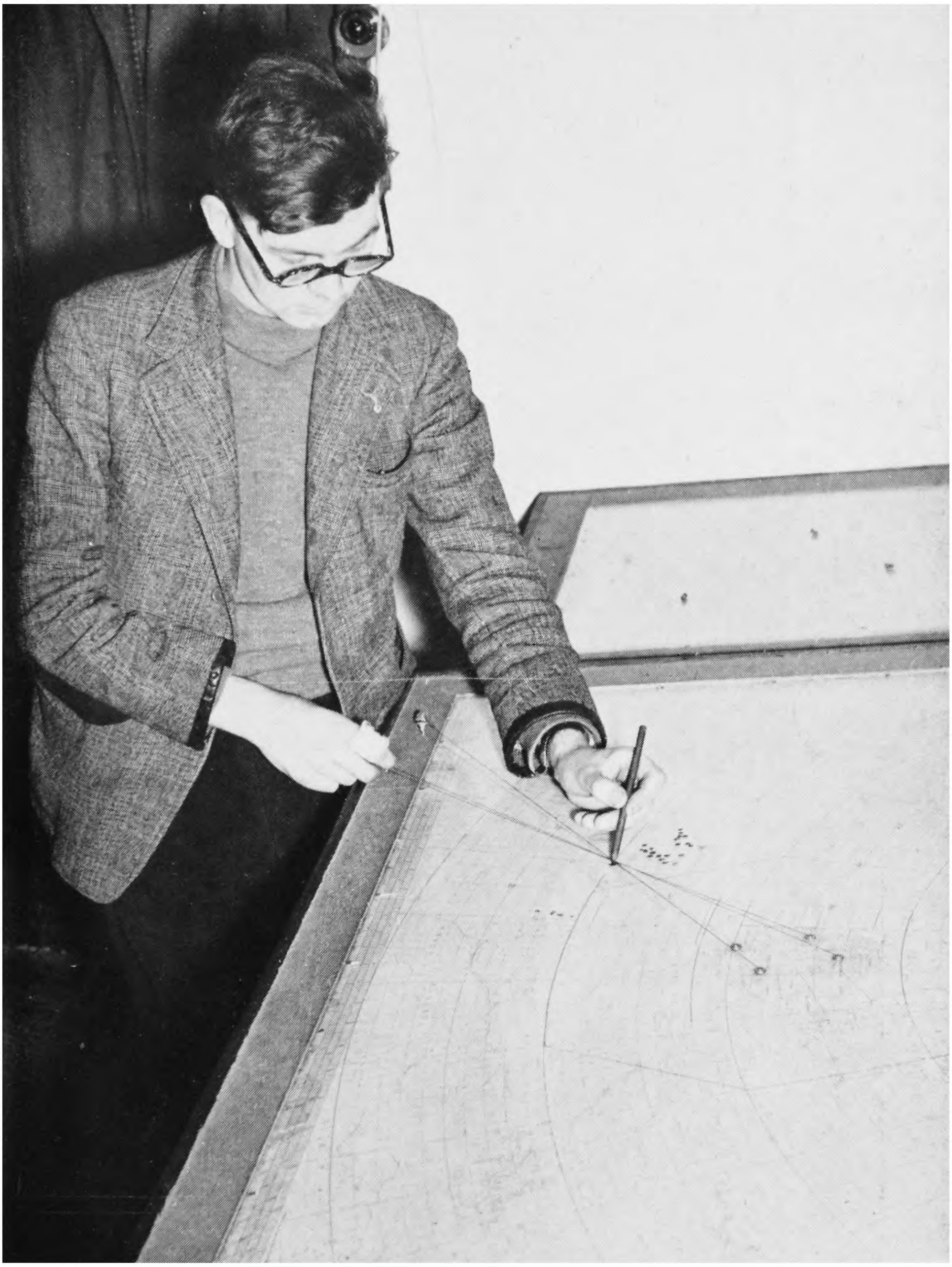
Photo by R.A.F.

CIRRUS AND CIRROSTRATUS ABOVE ALTOCUMULUS
Taken at 10,000 ft. over England, 1400 G.M.T., January 4, 1949



CATHODE-RAY TUBE USED FOR " SFERIC " OBSERVATIONS

Sferics are observed as a " pointer " of light passing through the centre of the screen; the bearing is read on the circular scale 0—360° surrounding the tube (see *Met. Mag., London*, **76**, 1947, p. 78).



PLOTTING " SFERIC " OBSERVATIONS AT THE CENTRAL FORECASTING OFFICE, DUNSTABLE

Bearings of " sferics " or thunderstorm discharges are made simultaneously at two or more stations in the British Isles. These observations are plotted on the chart as shown, and the location of the discharge is given by the intersection of the bearings.

Reproduced by courtesy of Sport and General Press Agency Ltd.
Capt. E. A. Holland receiving barograph from Cdr. C. E. N. Franckom, R.N.R., in the court room aboard the *Wellington*

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PRESENTATIONS TO LINER CAPTAINS

On the bench listening to Capt. C. E. Duggan replying after the presentation are (left to right) Capt. G. C. Saul, Warden; Sir Nelson Johnson, Director of the Meteorological Office; Air Chief Marshal Sir Frederick Bowhill, Master of Company; Capt. St. G. Glasson, Deputy Master; Mr. W. T. C. Smith, Clerk to Hon. Company. (see p. 89) variables, in such a way that $w_1(\lambda) > w_1(\lambda_0)$ if $\lambda > \lambda_0$. It is now easy to see why the shorter wave-lengths are more affected by super-refraction than the longer wave-lengths, since for a duct of given width, for a sufficiently long wave-length the track width of the first mode will exceed the duct height and no mode is trapped. As the wave-length is reduced the H_1 wave is trapped, and by further reducing the wave-length the H_2 mode is also trapped, which means that more energy is guided in the duct. On further reduction the H_3 mode is also trapped, giving more guided energy. For example with a uniform lapse of modified refractive index, a duct just failing to trap the first mode of a 10-cm. wave-length transmitter would trap two modes, the $H_1(3)$ and $H_2(3)$ modes, of a 3-cm. wave-length transmittter, and under the same conditions a duct trapping $H_1(10)$ and $H_2(10)$ would trap $H_1(3)$, $H_2(3)$ . . . $H_5(3)$.

The use of the wave theory allows calculations of field strength, but this is a radio problem.

The meteorologist requires the practical knowledge of the order of duct height necessary to produce super-refraction on a given wave-length. This is unfortunately not an easy problem to answer, since it depends upon many variables but a good idea of the order is given by the following approximate formula

$$D = 25\ \lambda^{2/3}\text{ft.}$$

where D is the duct width necessary to trap the first mode of signal of wave-length λ cm, so that for a wave-length of 3 cm. the duct width is of the order of 55 ft. and for 10 cm. of the order 120 ft.

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METEOROLOGICAL OFFICE DISCUSSION

The fourth discussion of the 1949–50 series, held at the Imperial College on January 9, 1950, dealt with the problem of the turbulent exchange of water vapour, heat, and momentum near the ground. The discussion was opened by Mr. F. Pasquill with a description of observational work carried out by a Meteorological Office Unit at the School of Agriculture, Cambridge, during the past three years.

The Cambridge work had been aimed initially at establishing methods of deriving the local rate of evaporation from a land surface. Recognition of the limitations of conventional evaporimeter technique and of the difficulty of making in general a direct measurement of evaporation loss from the ground, had previously led to two meteorological approaches in which evaporation was related to processes of turbulent exchange and energy exchange near the ground. In order to examine the basic features of these two approaches measurements were made in selected conditions of the water loss over periods of about one hour from isolated but otherwise naturally exposed samples of the surface layer of clayland under grass[1 2*]. These included control measurements in terms of which the adoption of the observed water losses as true evaporation losses was partially justified. The vertical profiles of air temperature, humidity[3] and wind speed were explored in the height range 25–200 cm. and on some occasions, for heat balance considerations, these observations were supplemented[1] by meaurements of the vertical profiles of soil temperature and soil moisture in about the first foot, and of incoming and reflected solar radiation. Long-wave radiation was computed from the Kew radiation chart. Preliminary measurements were also made of the aerodynamic drag of grassland[4].

Summarising the results obtained Mr. Pasquill first referred to the support provided for the validity, in an adiabatic lower atmosphere over grassland, of a law relating drag and wind profile identical with that thoroughly established in aerodynamic work. The eddy diffusivities for momentum, K_m, following from this law were then shown to be in agreement with those for water vapour, K_v, derived from the evaporation and vapour profile measurements in adiabatic conditions. In practice this result leads to a simple formula for evaporation in terms of humidity at two heights and wind speed at two or three heights.

The increases of eddy diffusivity, K_v, in unstable conditions and the decrease in stable conditions were quantitatively demonstrated in systematic relation to the Richardson Number. Since the stability influence decreases rapidly as the ground is approached the relations established for adiabatic flow may be applied in other conditions, as a convenient and reasonable approximation, provided the profiles are observed sufficiently close to the ground[5], say below 50 cm. A general *a priori* quantitative explanation of the stability influence did not however seem possible at present. A useful result followed from considerations of the empirical wind-profile law recently put forward by Deacon, in that values of K_m computed from this law were in good agreement with those observed for K_v in unstable conditions, though in stable conditions a considerable disparity appeared.

The heat-balance observations lead to values of the eddy diffusivity for heat, K_h, sensibly equal to those of K_v, in stable conditions but in unstable conditions K_h was systematically the greater. The latter feature is qualitatively consistent with the broader implications of Priestley and Swinbank's modification of the classical treatment of the turbulent transport of heat. Furthermore, this result means that the conventional heat balance method of estimating evaporation (assuming K_h equal to K_v) may seriously over-estimate the rate of evaporation.

In concluding his remarks Mr. Pasquill pointed out that the work described had been regarded entirely in the light of what might be termed the " bulk property " approach to problems of turbulent diffusion. The more difficult but more satisfying approach, in terms of the intimate turbulent structure of the fluid, was still in a very early stage as far as the atmosphere was concerned, but it was to be hoped that it would not be long before such considerations would be effectively applied to problems of the type which had been discussed.

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*The index numbers refer to the list of references on p. 85.

The Director, opening the general discussion, commented on the advance which had been made in the provision of numerical values for the quantities occurring in the equations of turbulent transport, and thought that it was especially interesting to see some experimental support for the Priestley and Swinbank theory that the eddy diffusivities for different physical properties might differ in non-adiabatic conditions.

Mr. Pasquill, replying to a query from the Director, confirmed that the observed evaporation in stable conditions was widely at variance with the values computed from the Deacon wind-profile law. It was clear that careful observations of the drag-wind profile relation in non-adiabatic conditions were required as a first step in elucidating this point.

Dr. G. D. Robinson said he would have liked to have heard more about the actual measurements. Commenting on the difficulty of evaluating gradients from the profile observations he favoured the graphical method adopted in similar work at Kew rather than the numerical procedure adopted in some of Pasquill's analysis. The Kew observations had been used to compute evaporation on the conventional heat-balance method and the aerodynamic method, and the two methods gave the same answer. Furthermore, the observed profiles of temperature and humidity showed good agreement. These results supported the equality of K_h and K_v in both unstable and stable conditions in the height range up to 50 cm., in contradiction to Pasquill's result. The wind profile measurements at Kew had not confirmed Deacon's results. On the question of the flux equations the familiar relation defining the eddy diffusivity had previously been justified by the mixing-length theory of diffusion. If the latter theory was no longer to be accepted then the flux-gradient relation could only be looked upon as an assumption to be justified by observation.

Mr. Pasquill stated that the method of evaluating gradients would not affect the essential implications of the Cambridge results. In any case part of the analysis had been carried out without deriving gradients as such. Whatever analytical approach was used the undeniable experimental " scatter " in the observations appeared ultimately as casual variations in the final results, some examples of which had been given in the opening remarks. In examining the Cambridge results on vapour and heat transfer it was not thought that any critical test of the relative magnitudes of K_h and K_v could be provided by the profile forms alone. The crucial test was provided by the specified absolute magnitudes of the vapour flux and heat flux. Perhaps the difference in the Kew and Cambridge results was partly due to a difference in surface conditions. Following the arguments of Priestley and Swinbank differences in K_h and K_v may appear as a result of a correlation in the temperature and vapour structure in the air. Immediately above a patchy grass surface, such as that on which the Cambridge observations were made, it seemed reasonable to suppose that, relatively speaking, warm air would be dry and cool air moist. With negative gradients of both temperature and vapour pressure this would tend to give more effective upward transport of heat than of vapour, so possibly explaining the $K_h > K_v$ result in unstable conditions.

Prof. P. A. Sheppard commented on the numerical consistency evident in the Cambridge results. Equality of K_m and K_v had also been demonstrated near the ground by observations on the diffusion of smoke. The result was certainly to be anticipated in this region of the atmosphere, but for larger-scale atmospheric processes the influence of the pressure field would be important and the situation might then be different. As regards the equality of K_h and K_v demonstrated in stable conditions and the difference in unstable conditions, was this result an indication of a change in the physical process of turbulent exchange ?

Mr. Pasquill replied that he had not considered the matter on those lines but that his previous tentative argument could equally be applied to the stable case. In the Cambridge observations, however, the vapour gradient was still negative, while the temperature gradient was of course positive, and if a correlation of the type suggested still held it was conceivable that the vapour flux (upward) and the heat flux (downward) would be influenced to a similar degree, so maintaining approximate equality in the apparent values of K_h and K_v.

Mr. R. W. Gloyne queried the validity of applying an evaporation formula established by measurements with a saturated top soil to occasions when the top soil was dry or when plants were drawing water from deeper levels. He asked if in the evaporation measurements any data had been obtained on the influence of the Tufnol container on the temperature of the soil in the evaporimeter.

Mr. Pasquill explained that the formula given for evaporation was exclusively concerned with physical processes in the air above the ground and was clearly independent of the processes of water movement in the soil. Having established it against test measurements of evaporation in selected circumstances it could naturally be taken to apply whatever the conditions of soil moisture. Further, there was no *a priori* reason why it should not apply to a surface under crops, though with the large-scale roughness elements then involved the profile observations would have to be carefully interpreted as regards " zero plane displacement", and the representative nature of observations taken at a single site. No measurements had been made of soil temperature inside the evaporimeters, but it had been verified that the thermal properties of the evaporimeter walls were similar in order to those of soil. A more likely cause of thermal disturbance was the difficulty of ensuring intimate contact at the bottoms of the evaporimeters.

Mr. D. J. Holland drew attention to the formulae now used in computing the concentrations arising from ground-level sources of smoke and vapour. These were still only known to apply to diffusion in the first few metres, and it was important that they should be generalised so as to be applicable to a greater height range. The variation of shearing stress with height would be of particular importance in this connexion.

Dr. F. J. Scrase inquired about the significance of the evaporation measurements made by botanists using the Piché evaporimeter. Pasquill's approach was too complex for normal use.

Mr. Pasquill thought that one might reasonably assume the results to approximate to the evaporation from say a transpiring leaf similar in size and exposure to the evaporating surface of the Piché instrument, but that they could hardly be regarded as representative of the evaporation from a natural assemblage of leaves.

Prof. Sheppard doubted if the indications of the so-called evaporimeters meant anything at all, and thought that much more relianc ecould be placed on indirect estimates from meteorological data. Going back to the earlier discussion on the flux-gradient relation he said he agreed wholeheartedly with Dr. Robinson in that we could only regard the customary form as a convenient assumption. The " K " approach had now been stretched as far as it would go; some new physical ideas and a re-casting of the whole approach to the turbulent diffusion were required.

Mr. L. P. Smith stated that he had computed evaporation for about 50 stations using Dr. Penman's method. One feature of particular interest which had emerged was that the computed values were entirely consistent with the observed drying out of the Hereford pastures prior to those in Worcester. It was clearly a matter of great economic importance to be able to advise agriculturists on irrigation requirements.

Dr. Robinson pointed out that although few seemed to have a good word for the evaporation tank nevertheless over a long period its indications were consistent with the water engineers' estimates of rainfall minus run-off. Comparisons at Kew between tank indications and heat-balance estimates had shown reasonable agreement over the day-time period when the grass was in a fresh condition, but the tank indications were higher when the grass was dry and withered. Furthermore, the estimated values were usually lower than the tank indications at night.

Dr. R. C. Sutcliffe drew attention to the problem of forecasting evaporation and to the need for estimating evaporation in a practical way. From the latter point of view there seemed to be much in favour of the method used by Dr. Penman, and it was perhaps desirable to link Penman's and Pasquill's methods.

Mr. Pasquill emphasised that the work which he had described had not, in the first instance, been concerned with providing data on the lines required by Dr. Sutcliffe. The object had been to examine the problem from as fundamental a standpoint as possible. In this respect it should be realised that, although Dr. Penman's method appears finally in a form requiring only routine meteorological data, the justification for its general application must depend on a fundamental basis which, however, differed in many respects from that followed in the work which had been described in the opening of the discussion. Having clarified basic principles, then, for practical purposes, there was no reason why one should not reduce equations, which imposed exacting observational requirements, to forms which could be evaluated from cruder data, providing one bore in mind the approximations necessarily introduced.

The Director, referring to the last part of the discussion, drew attention to the important role of soil temperature in any considerations of evaporation in relation to routine meteorological data.

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METEOROLOGICAL RESEARCH COMMITTEE

The seventh meeting of the Instruments Sub-Committee of the Meteorological Research Committee was held on January 26, 1950.

The Sub-Committee considered the Chairman's Report to the Committee and also drew up recommendations for revision of that part of the research programme which deals with instrumental matters.

Among the papers discussed was one by Mr. Shellard[1] dealing with the variation with altitude of the speed correction to aircraft thermometers.

[1] *Met. Res. Pap., London.*, No. 527, 1949.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society, held at 49 Cromwell Road on December 21, 1949, with Sir Robert Watson-Watt in the Chair, the following papers were read.

M. K. Miles—Air motion ahead of warm fronts

Mr. Miles explained how the ageostrophic wind ahead of a warm front was obtained by graphical solution of the equation

$$\mathbf{V} = \mathbf{J} + \mathbf{A}$$

where **V**, the observed wind, was extracted from the 900-mb. level of an upper-wind sounding and **J**, the geostrophic wind, was measured by the pressure gradient on a surface chart. Components of A normal to the fronts were in fair agreement with the frontal speeds, showing that A had some significance.

Comparison of A with the isallobaric and geostrophic vectors indicated a limited relationship. The change in pressure gradient with time along the trajectory of the air (J') was shown to be closely related to A, where

$$|A| = 0{\cdot}78J' - 1{\cdot}0$$

The angle ϕ between A and J' was found to lie between 20° and 50°. It was concluded that the motion of the cold air was not quasi-geostrophic.

Assuming an exponential growth of gradient where $J \propto e^{kt}$, the ratio $|A|/J'$ was found to agree with the calculated value when k lay between 0·4 and 0·45 hr.^{-1}. Allowing for possible errors, ϕ was found to be about 45°. These results were illustrated graphically by Mr. Miles.

Among points raised in the discussion, Mr. Matthewman disagreed with the growth of gradient used by Miles, and produced smaller values of k. Mr. Douglas pointed out the difficulties of measuring isallobaric and ageostrophic winds, and said that investigation into cold-front motion was also required. Mr. Sawyer pointed out that a component of A was still unexplained and wondered why exponential growths were assumed. Dr. Sutcliffe was glad that acceleration and not friction seemed to be responsible, though the complete dynamics had not yet been worked out.

In reply, Mr. Miles said that growths other than exponential do not fit. Friction was a small effect.

F. H. Ludlam—The composition of coagulation elements in cumulonimbus

Mr. Ludlam said that in a cumulonimbus cloud the initial concentration of ice crystals is low compared with that of liquid water droplets. Ice crystals should not interfere with each other's growth. Water contents of clouds may be obtained from an aerological diagram; summer clouds will contain about 7 gm./m.^3 compared with winter values of 1 gm./m.^3.

When an ice particle reaches a diameter of 1 mm. and the water content of the cloud exceeds 1 gm./m.^{3}, further growth will be controlled by coagulation with water drops in the path of the particle. A film of water on the particle will freeze liberating latent heat. The temperature will not rise to 0°C. since heat is lost by conduction to the surroundings and by evaporation from the water surface.

Dr. Ludlam then showed how the heat loss will be greatest when the water surface is at 0°C., and illustrated graphically the critical concentrations of water vapour required to produce a wet growth for various temperatures and water-drop sizes. Small elements less than 1 mm. thick and large elements associated with low water content can grow as frozen structures. When the water content is high, large elements can accumulate water down to temperatures of about −30°C. Drops may also break up if they become too large. The layered appearance of hailstones can therefore be accounted for without complex vertical motion.

The presence of coagulation elements may throw light on problems relating to thunderstorms and radar echoes. " Splintering " of large complex ice crystals is associated with the development of thunderstorm charges. It seems likely that thunderstorms will develop when cloud temperatures are below −32°C., otherwise the large particles would be wet coagulation products.

Dr. Wexler queried the size and growth of the particles and wondered how diffusion could account for them. Mr. Fournier d'Albe asked if the products had time to grow.

Mr. Ludlam, replying, said that in view of the high water content, he assumed large droplets; these would be picked up by the falling ice particles. A few minutes was sufficient for the growth of coagulation elements.

OFFICIAL PUBLICATION

The following publication has recently been issued:—

METEOROLOGICAL REPORTS

No. 4—*Aviation meteorology of the route Marseilles—Castel Benito*

This report describes the climate of the air route from the south of France to Tripolitania with special attention to factors affecting aviation. The various types of weather situation are described and their relation to the movement of depressions and fronts across the route. Visibility, cloud, wind, rainfall, etc., are discussed individually and notes on local conditions at airfields are included. A number of climatic tables are given.

The broad picture presented is one of settled fine weather in summer with only brief interruptions affecting the north. In winter disturbed conditions are as common as over north-west Europe, but the extensive low cloud and areas of bad visibility, frequent over north-west Europe, rarely occur for long over the Mediterranean. On the other hand, convectional weather, showers, cumulonimbus cloud, thunder and turbulence are just as common over the route in winter as over north-west Europe.

LETTER TO THE EDITOR

Luminous night clouds

In a very interesting article on these clouds in the *Meteorological Magazine* for December 1949, Mr. Paton refers to the two alternative suggestions which have been made regarding the composition of these clouds, *viz.* (*a*) that they are clouds of dust of either volcanic or cosmic origin or (*b*) that they are clouds of water (ice) resembling cirrus clouds. It seems to me that Mr. Paton's own observation, which he describes in the article, goes far to decide this question. Describing the appearance of the clouds on July 10–11, 1949, he says that the main cirrus-like clouds showed " only a slow change in form with time " but " by contrast, the background showed continuous change, sometimes appearing as a perfectly uniform sheet, then suddenly developing within itself thin parallel waves. . . ."

It is difficult to see how a layer of dust could change its appearance as this background cloud did, but such changes would be readily understood if it was a water cloud and indeed similar changes can constantly be seen in cirrus clouds. If the background cloud were a water cloud, there is strong presumption that the whole cloud was also a water cloud.

G. M. B. DOBSON

Watch Hill, The Ridings, Shotover, Oxford, December 29, 1949

[While observing the development and disappearance of parallel waves in the thin background of the night clouds, so very like the changes that occur in cirrus clouds, I felt convinced, like Dr. Dobson, that they could be explained only by assuming that these were water clouds. Later reference, however, to Professor Brunt's account and photographs* of artificial smoke clouds suggested that, despite the vast difference in scale, such changes might occur in air-borne dust through wind shear. Perhaps the observed thin background is simply dust moving vertically to join the main clouds at the discontinuity at 80–90 Km. and the waves develop on passage through a region of rapid shear ? It may be significant in this connexion that the background is most dense at lower elevations. Examination of the photographs shows that the solid cloud streaks stand out against an almost dark background in the upper portions of the cloud mass.

Then, if these were water clouds, would not many of the particles, slow though their rate of growth must be, eventually develop to the size when selective scattering of the blue would cease ? Yet during the whole period of three hours while we observed them, the clouds remained brilliantly blue in colour. Only the edges and thinner parts appeared grey-white, but presumably this was due to low luminosity, below the threshold of colour perception. Investigation of the nature of changes in the profile of the spectrum during a display would reveal if growth of the particles beyond dimensions of the order of the wave-length of visible light actually occurs—J. PATON].

NOTES AND NEWS

Universal Decimal Classification

551.5 Meteorology

The Secretariat of the International Meteorological Organization has drawn our attention to the statement which appears at the end of the first paragraph on page 60 of the *Meteorological Magazine* for February 1950, where it is stated that the revised Section 551.5 of the Universal Decimal Classification, as agreed between the International Meteorological Organization and the International Federation for Documentation, will be published as an amendment to I.M.O.

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*BRUNT, D.; Natural and artificial clouds. *Quart. J. R. met. Soc., London,* **63**, 1937, p. 277.

Publication No. 61. The Secretariat point out that the form in which this information will be published has not yet been decided, but that it will not be as an amendment to Publication No. 61. We will inform our readers about the way in which the I.M.O. decide to publish this information as soon as the matter has been decided.

Meteorological occasion at the Honourable Company of Master Mariners

On January 18, in the colourful Court Room of the *Wellington*, Headquarters' ship of the Honourable Company of Master Mariners, an impressive little meteorological ceremony took place. The occasion was the presentation of barographs by the Director of the Meteorological Office to three master mariners, in recognition of long and meritorious service as voluntary meteorological observers (see photographs facing p. 81).

The recipients were Captain Holland, recently retired from command of the New Zealand Shipping Company's steamer *Rangitiki*, Captain Duggan, now in command of the Canadian Pacific S.S. *Empress of Australia*, and Captain Johnston, in command of the Blue Funnel steamer *Indomeneus*. Captains Holland and Duggan have been voluntary observers since 1921 and Captain Johnston since 1923. During their many years of voluntary work for the Meteorological Office, the records sent in by them have been of a consistently high standard. A similar presentation was made to Captain Patchett of the Cunard White Star Line's steamer *Vardulia*, aboard that ship at Liverpool in December 1949.

The guests included the Marine Superintendents of the three Companies concerned and several other well known figures in the shipping world. Seated on the dais during the ceremony were the Master of the Honourable Company, Sir Frederick Bowhill, the Deputy Master, the Senior Warden and the Clerk, in the ceremonial robes of a City Company, and the Director of the Meteorological Office. Sir Frederick welcomed the guests on behalf of the Honourable Company.

Commander Frankcom, Marine Superintendent, Meteorological Office, in making the presentations on behalf of the Director, congratulated the recipients upon their fine work and stressed the long and agreeable association between the Meteorological Office and the shipping companies concerned, which dated back in one case to 1876. Captain Johnston was unfortunately unable to be present and Captain Glasier, Marine Superintendent, deputised for him.

The Director gave warm thanks to the Merchant Navy for their ever ready co-operation with the Meteorological Office, without which our information about the weather in the oceans, despite the presence of special weather ships, would be quite inadequate.

After the ceremony the Honourable Company entertained the guests to tea.

C. E. N. FRANKCOM

Radar Echoes from Smoke

On August 18, 1949, routine observations were being made at East Hill using the 10-cm. A.M.E.S. Type 21 radar when at about 1400 G.M.T. an unexpectedly bright echo was observed on the P.P.I. display on a bearing of 184° magnetic at a range of 28 miles. Viewed on the height-range indicator the echo appeared as a narrow column of quite high intensity with a top extending to 6,000 ft. (see photograph facing p. 80).

Except for the small vertical extent, the echo was very similar to that from a cumulonimbus cloud giving a heavy shower at that point. The upper air ascents and general meteorological situation ruled out any possibility of cumulonimbus development, or indeed precipitation of any sort, in that area, but in view of the fact that the echo was being received from a point within 5 miles of Northolt confirmation was sought from the Meteorological Office there. Observation at Northolt confirmed that there was no sign of precipitation in that area but an enormous column of smoke was observed from a fire which had just broken out. This column of smoke was rising to a height of about 6,000 ft. and then spreading out under an inversion at that height. Newspaper reports on the following day revealed that the fire originated in a dump containing 800 tons of baled cork which covered an area of ¼ acre. Radar responses from this area continued for about an hour before gradually fading away.

Cases of cumulonimbus formation due to fires have been reported occasionally and such cases would undoubtedly have given a radar echo from the cumulonimbus so formed, but I have no knowledge of any other observation in which it is virtually certain that the echo received came from the column of smoke.

R. F. JONES

REVIEWS

Atmospheric Turbulence. By O. G. Sutton. Methuen's Monographs on physical subjects. 8vo, 6½ in. × 4 in., pp. viii + 107. *Illus.* Methuen and Co. Ltd., London, 1949. 6*s.* 0*d.*

One result of the lack of a completely satisfactory theory of atmospheric turbulence is that the most useful theory for any given set of circumstances depends upon the circumstances. Prof. Sutton has performed an extremely valuable task in this little monograph in summarising the present state of knowledge of the subject in a way which brings out the limitations of the various theories without obscuring the broad picture by a multitude of details.

The book opens with two chapters of a general nature dealing with turbulence in general and the meteorology of the lower atmosphere respectively. The third chapter deals with the old K-theory and its application to phenomena within the friction layer. The mixing length and statistical theories of turbulence are explained in Chapter 4 with some emphasis upon the distinction between aerodynamically smooth and rough flow. Chapter 5 deals with the diffusion of matter—including evaporation— in terms of the statistical theory and the final chapter discusses turbulence in a variable-density gradient.

This volume can be strongly recommended not only to workers in other fields—for whom the series is intended—but also to the professional meteorologist who is interested in the turbulence of the lower atmosphere.

A. C. BEST

Oscillations of the earth's atmosphere. By M. V. Wilkes. Cambridge Monographs on Physics. 8vo, 8½ in. × 5½ in., pp. ix + 76. *Illus.* University Press Cambridge, 1949. 12*s.* 6*d.*

This is one of the first volumes of a new series of " Monographs on physics " issued by the Cambridge University Press and it deals with the subject of the solar and lunar tides of the earth's atmosphere. The first chapter contains an excellent summary of the observational data and the story of the way in which Chapman, Simpson, Pekeris and others disentangled the small pressure variations involved from these data. The author then passes to the mathematical theory of these tides in terms of the resonance theory in which the tide-producing force and the divergence of the velocity are assumed to have identical periods. The resulting differential equations are complicated and their solutions naturally lead to numerical computations, which are briefly described. In the fourth chapter, the resonance theory is interpreted in terms of the " trapping " of energy by a discontinuity of temperature. If the temperature of the upper part of the atmosphere is less (by an appropriate amount) than that of the lower, energy cannot cross the discontinuity and a resonance oscillation is set up of the required 12-hourly period. The last chapter is devoted to a general discussion of the results, particularly with regard to the effects of successive layers of high and low temperature in the atmosphere up to 180 Km. and to the difficulties found in accounting for the oscillations of the E and F layers.

The book, especially in its mathematical portions, is not an easy one to read, as might be expected when so much has to be compressed into so short a space. There are some minor defects which could be corrected in later editions. The legend of Fig. 9 is incomplete, the definition of the velocity-component u on p. 26 does not agree with that on p. 41, and the x-co-ordinate on p. 35 is " southerly " not " northerly ". In the fundamental equations (11) and (12) on p. 27 there is made an additional unstated assumption, *viz.* that the contribution of the vertical velocity to the horizontal acceleration is negligible. It is unfortunate that σ is used on p. 42 for the density of the earth whereas elsewhere $2\pi/\sigma$ is the period of an oscillation. Finally the opening sentence of Chapter IV is misleading: it has not been shown, but assumed, in Chapter II that the tide-producing force can be resolved into a set of components, each of which excites a mode of oscillation of the atmosphere. In spite, however, of such minor blemishes, every mathematically minded meteorologist will value this book for its presentation of the resonance theory in so accessible and excellently produced form.

G. C. MCVITTIE

ERRATUM

February 1950, page 56, line 5; *for* G. I. Finch *read* S. Chapman.

METEOROLOGICAL OFFICE NEWS

Message from the Director.—Starting with this number, two pages of the *Meteorological Magazine* will be devoted to Meteorological Office News as a regular feature. One of the objects is to let you know our policy and plans in matters generally, so that you will understand and be able to take an intelligent interest in the part you are called upon to play in carrying out those plans. Another purpose of Meteorological Office News is to tell you what is going on in various parts of the Office at home and overseas—items of interest which you might not otherwise hear about.

We shall try to keep these two pages as human and personal as possible, and to make them serve as a House Magazine in miniature.

All members of the staff are invited at any time to send to M.O.20 any piece of information they think might be of general interest, and to suggest any topic upon which they feel that some guidance or enlightenment would be helpful.

N. K. JOHNSON

Napier Shaw Laboratory for forecasting research.—A fine new building of spacious and pleasing design was occupied by the Forecasting Research Division in January. The building provides accommodation for the scientific officers and assistants engaged in research at Dunstable. There is also a technical library, a reading and a conference room, and space for the storage of past records in a readily accessible form.

Weather ships.—During 1949 station J was manned by one or other of the British ocean weather ships on 356 days, and station I on 343 days. The stations were left without ships only to land sick members of crews for hospital treatment, or to carry out search for aircraft or ships reported in distress. In one period the more northerly station I was vacated to take up a position nearer the flight track of some U.S.A. jet aircraft flying from Iceland to Scotland.

Scientific assistants.—The continuing shortage of assistants is making it impracticable to provide all the assistants needed at some outstations and in Headquarters Branches, and it is realised that at the under-staffed units both officers and assistants are undertaking a correspondingly heavier share of duties. The Director appreciates their loyal co-operation during a difficult period.

The recruiting campaign for more assistants is being intensified, and it is hoped that the response will lead to a lightening of the burden borne by the staff.

Assistants themselves, and indeed all Meteorological Office staff, can help in the campaign by letting it be known that anyone who has obtained a credit in mathematics or physics in the School Certificate Examination may apply for an assistant post in the Office.

Establishment of assistants.—Those assistants who have not yet been established, and who have had two years' experience of technical work since leaving school (although not necessarily while in the Meteorological Office) should enter the competition for establishment announced in the Meteorological Office Orders. Besides leading to permanent appointments, establishment is the first step on the ladder of advancement, and it also carries improved salary scales and longer annual leave. Assistants who may be in doubt about their eligibility to enter the competition should write immediately to M.O.10. The closing date for applications is March 31, 1950.

Sports and social activities.—The Meteorological Office has so far accumulated a total of 42 points in the effort to retain the Bishop Shield which the Office won last year. The Swimming Championships brought 29 points, and the Cross Country Championships 13.

In the Air Ministry Cross-Country Championships Mr. E. W. Heasman, Assistant at Uxbridge, was first, and Mr. W. Lawson from Middleton St. George was third: in the Team Race the Meteorological Office team of E. W. Heasman, W. Lawson, G. Marriott and G. M. Band was first.

The Meteorological Office, Harrow, has formed a Social and Sports Club which, like the similar club at the Central Forecasting Office, Dunstable, is affiliated to the Meteorological Office Social and Sports Committee. The Officers of the Harrow club are: Mr.R. H. Mathews (President), Mr. G. J. Evans (Chairman), Mr. G. F. Tindall (Secretary) and Mr. L. P. Smith (Treasurer). Besides having teams for netball and football, the club is organising indoor activities for the winter evenings including fencing, table tennis, bridge, chess,etc.

Appreciations.—Letter dated November 30, 1949, from Sir Basil Brooke, Prime Minister of Northern Ireland, to Air Commodore B. V. Reynolds, A.O.C.-in-C., R.A.F., Northern Ireland:

> Would you be so kind as to convey to your meteorological officers my appreciation of the help they gave me in forecasting weather conditions on Friday last, and my congratulations on the extraordinary accuracy of their report.
>
> I had to leave Belfast early on Friday morning to travel by road to Derry where I was to receive the Freedom of the City. Lady Brooke was due to arrive from Liverpool on Friday morning and I was most anxious to know whether there was any likelihood of her boat being delayed. Your people, however, were able to assure me that there was no likelihood of fog on the Irish Sea; that there would be a smooth crossing; that road conditions here would be excellent except for the presence of light fog from Dungiven on to Derry.
>
> Every one of their forecasts was 100 per cent. accurate and I am most grateful for their courteous attention to my request.

Letter dated December 19, 1949, from City Engineer, Sheffield, to the Senior Meteorological Officer, R.A.F. Station, Bawtry:

> The helpfulness and co-operation rendered by your office in times of snowfall and frost are greatly appreciated in this department and go a long way towards reducing to a minimum the inconvenience suffered by the public of Sheffield at those times. . . .

Radio-sonde work at Lerwick Observatory.—At the time of the early morning ascent on a day this winter the surface wind was 73 m.p.h. during the launching period, with gusts to 89 m.p.h. Both launching cones became unserviceable, but the balloon and its equipment were successfully launched by hand after 3½ hours of strenuous effort.

Retirement.—Mrs. M. Rookledge has retired after seven years as part-time Assistant in M.O.9. Mrs. Rookledge, who was then Miss Bigglestone, previously served in the Climatological Division of the Office from 1915 to 1922.

Future plans.—Even before 1939, the Headquarters Branches of the Office were separated from each other, administration and forecasting in Kingsway, climatology and instruments in South Kensington. In 1939 there was further dispersal, as almost all but the administrative staff were evacuated to the provinces. After the war the climatological, marine and instruments branches reassembled at Harrow, the Central Forecasting Office remained at Dunstable and the other headquarters staff continued at Victory House, London.

It has now been decided to accept an invitation from the Dunstable Borough Council to establish in Dunstable a permanent Headquarters for all but the London administrative staff. It will be some years before the plan can be fully implemented.

WEATHER OF JANUARY 1950

Mean pressure was above 1020 mb. over most of Europe, Canada and the eastern half of the United States, and was nearly 1030 mb. in Yukon and around Bermuda. It was a little below 990 mb. off the south-east coast of Greenland between about latitudes 60°N. and 65°N. The mean was nearly 20 mb. above the average in Yukon and northern Sweden, and 10 mb. below it off the south-east coast of Greenland.

In the British Isles the weather was extremely mild during the first half of the month and really cold during the second half. It was dry over the country as a whole and very dry over much of the southern half of England; for example it was the driest January in Birmingham since records began in 1893 and at Ross-on-Wye since the very dry January of 1898. Apart from a few scattered places sunshine was deficient especially in parts of England and south-east Scotland; at Wakefield it was the dullest month in their record back to 1915.

During the opening days an anticyclone remained almost stationary off our south-west coasts, while Atlantic depressions moved north-east and associated troughs moved east across the British Isles occasioning mild, unsettled weather with rain at times in most areas though falls were slight in the south. By the 6th the anticyclone had moved east and decreased somewhat in intensity, while the north Atlantic was covered by a complex deep depression and a very mild airstream covered the British Isles; heavy rain fell locally in the north-west (2·47 in. at Fort William) but little or none occurred in the south-east. Subsequently pressure continued low over the Atlantic and relatively high over Italy and the central Mediterranean and, during the ensuing days, rain, mainly slight, occurred chiefly in the west and north. From the 10th to 12th a very deep depression in mid Atlantic moved quickly north-east, while an anticyclone over the Bay of Biscay moved north-east and another over the Baltic moved south; further slight rain occurred in the west and north. Temperature reached or exceeded 55°F. locally on a number of days, for example, on the 7th, 8th, 9th and 11th (57°F. at Burnley, and 58°F. at Darwen on the 9th, 59°F. at Harwarden and 58°F. at Leeming, Church Fenton and Huddersfield on the 11th). Minimum temperatures were also very high at times, being as much as 50°F. or slightly above in places.

On the 14th a depression near Iceland moved away east and was followed by a ridge of high pressure associated with an anticyclone off our south-west coasts. By the 16th winds over the British Isles were north-west to north, and cooler, showery weather with bright periods prevailed on the 16th and 17th. By the 18th a fairly intense anticyclone was established over southern Scandinavia with a wedge extending over the British Isles. This distribution was maintained with little change until the 28th, with cold mainly dry weather, though some precipitation occurred chiefly in the north-west and north. On the 28th a trough of low pressure associated with a depression near Iceland caused heavy rainfall in south-west Ireland, and on the 30th the trough moved very slowly east and caused considerable snowfall north of a line from about mid Wales to Norfolk during the early hours. Later on the 30th a small depression developed off south-west Ireland and moved north-east and then north over western Ireland; this was associated with more snow in the northern half of the country. On the 30th snow was 9 in. deep at Forest-in-Teesdale and 6 in. at Ambleside and Chopwell Wood and on the 31st 8 in. at Oakes, Huddersfield, and 6 in. at Bellingham, Bingley and Harrogate. On high ground there was heavy drifting, for example, 4 ft. at Malham Tarn. In the south, moderate rain fell on the 30th and fairly heavy rain in London and parts of south-east England on the 31st. Gales were recorded locally in the west and north on the 28th–31st.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	61	12	+2·0	70	−8	88	..
Scotland	58	7	+1·5	90	−3	93	..
Northern Ireland ..	57	25	+0·1	53	−7	71	..

RAINFALL OF JANUARY 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ..	1·01	54	*Glam.*	Cardiff, Penylan ..	1·36	36
Kent	Folkestone, Cherry Gdn.	1·52	68	*Pemb.*	St. Ann's Head ..	1·35	39
,,	Edenbridge, Falconhurst	1·25	49	*Card.*	Aberystwyth	1·16	36
Sussex	Compton, Compton Ho.	1·42	45	*Radnor*	Tyrmynydd	2·97	47
,,	Worthing, Beach Ho.Pk.	·97	42	*Mont.*	Lake Vyrnwy	3·42	59
Hants	Ventnor, Roy. Nat. Hos.	1·71	67	*Mer.*	Blaenau Festiniog ..	8·73	87
,,	Bournemouth	·78	29	*Carn.*	Llandudno	1·00	41
,,	Sherborne St. John ..	·73	31	*Angl.*	Llanerchymedd ..	1·68	53
Herts.	Royston, Therfield Rec.	1·04	60	*I. Man.*	Douglas, Borough Cem.	2·38	71
Bucks.	Slough, Upton	·70	38	*Wigtown*	Port William, Monreith	2·27	70
Oxford	Oxford, Radcliffe ..	·55	30	*Dumf.*	Dumfries, Crichton R.I.	2·39	74
N'hant.	Wellingboro', Swanspool	·71	42	,,	Eskdalemuir Obsy. ..	4·74	88
Essex	Shoeburyness	1·41	104	*Roxb.*	Kelso, Floors	1·37	78
Suffolk	Campsea Ashe, High Ho.	1·41	77	*Peebles*	Stobo Castle	2·35	78
,,	Lowestoft Sec. School ..	1·26	75	*Berwick*	Marchmont House ..	1·32	59
,,	Bury St. Ed., Westley H.	1·31	73	*E. Loth.*	North Berwick Res. ..	·61	35
Norfolk	Sandringham Ho. Gdns.	·93	48	*Midl'n.*	Edinburgh, Blackf'd. H.	1·26	72
Wilts.	Bishops Cannings ..	·44	19	*Lanark*	Hamilton W. W., T'nhill	2·73	83
Dorset	Creech Grange.. ..	1·05	32	*Ayr*	Colmonell, Knockdolian	2·48	57
,,	Beaminster, East St. ..	·65	19	,,	Glen Afton, Ayr San ..	5·16	101
Devon	Teignmouth, Den Gdns.	·97	33	*Bute*	Rothesay, Ardencraig	3·61	80
,,	Cullompton	·85	26	*Argyll*	L. Sunart, Glenborrodale	6·42	91
,,	Barnstaple, N. Dev. Ath.	1·22	37	,,	Poltalloch	4·78	94
,,	Okehampton, Uplands	2·09	41	,,	Inveraray Castle ..	7·81	95
Cornwall	Bude, School House ..	1·28	42	,,	Islay, Eallabus	5·07	108
,,	Penzance, Morrab Gdns.	2·28	60	,,	Tiree	3·83	90
,,	St. Austell	2·89	67	*Kinross*	Loch Leven Sluice ..	2·37	87
,,	Scilly, Tresco Abbey ..	1·32	42	*Fife*	Leuchars Airfield ..	1·23	68
Glos.	Cirencester	·71	28	*Perth*	Loch Dhu	7·05	77
Salop.	Church Stretton ..	·84	32	,,	Crieff, Strathearn Hyd.	2·49	62
,,	Cheswardine Hall ..	·87	39	,,	Pitlochry, Fincastle ..	3·27	93
Worcs.	Malvern, Free Library	·45	20	*Angus*	Montrose, Sunnyside ..	1·54	77
Warwick	Birmingham, Edgbaston	·74	37	*Aberd.*	Braemar	1·74	55
Leics.	Thornton Reservoir ..	·71	36	,,	Dyce, Craibstone ..	2·37	100
Lincs.	Boston, Skirbeck ..	1·00	62	,,	Fyvie Castle	1·65	70
,,	Skegness, Marine Gdns.	1·08	62	*Moray*	Gordon Castle	1·61	80
Notts.	Mansfield, Carr Bank ..	1·01	47	*Nairn*	Nairn, Achareidh ..	1·81	100
Derby	Buxton, Terrace Slopes	3·16	71	*Inverness*	Loch Ness, Foyers ..	3·75	89
Ches.	Bidston Observatory ..	·73	34	,,	Glenquoich	10·71	78
Lancs.	Manchester, Whit. Park	1·80	72	,,	Fort William, Teviot ..	9·85	102
,,	Stonyhurst College ..	4·50	105	,,	Skye, Duntuilm ..	4·46	84
,,	Blackpool	1·68	62	*R. & C.*	Tain, Tarlogie House ..	3·28	134
Yorks.	Wakefield, Clarence Pk.	1·40	73	,,	Inverbroom, Glackour..	6.09	113
,,	Hull, Pearson Park ..	1·24	69	,,	Applecross Gardens ..	5·10	93
,,	Felixkirk, Mt. St. John	1·49	75	,,	Achnashellach	8·53	94
,,	York Museum	1·38	78	,,	Stornoway Airfield ..	3·55	72
,,	Scarborough	1·31	65	*Suth.*	Loch More, Achfary ..	7·10	98
,,	Middlesbrough.. ..	1·17	73	*Caith.*	Wick Airfield	3·47	14
,,	Baldersdale, Hury Res.	2·09	64	*Shetland*	Lerwick Observatory ..	4·14	97
Norl'd.	Newcastle, Leazes Pk. ..	1·45	73	*Ferm.*	Crom Castle	1·84	55
,,	Bellingham, High Green	2·36	83	*Armagh*	Armagh Observatory ..	1·75	69
,,	Lilburn Tower Gdns. ..	1·59	77	*Down*	Seaforde	1·28	41
Cumb.	Geltsdale	2·94	105	*Antrim*	Aldergrove Airfield ..	1·23	45
,,	Keswick, High Hill ..	4·03	80	,,	Ballymena, Harryville..	2·20	59
,,	Ravenglass, The Grove	2·33	70	*L'derry*	Garvagh, Moneydig ..	3·32	96
Mon.	Abergavenny, Larchfield	·88	26	,,	Londonderry, Creggan	4·42	123
Glam.	Ystalyfera, Wern House	2·97	47	*Tyrone*	Omagh, Edenfel ..	2·73	77

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, SEPTEMBER 1949

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1017·2	0·0	86	48	71·8	57·0	64·4	+6·9	59·8	81	6·2	0·35	−1·52	6	5·3	42
Gibraltar	1015·9	−1·3	90	63	82·4	68·8	75·6	+3·2	69·4	77	4·0	5·59	—	9	8·1	65
Malta	1018·8	+2·5	93	60	83·0	69·5	76·3	+0·3	70·7	62	2·1	0·00	—	0	10·8	87
St. Helena	1018·0	−0·7	68	51	62·5	54·6	58·5	+1·6	54·8	97	7·7	3·37	+1·12	16	—	—
Lungi, Sierra Leone	1013·4	—	87	69	84·0	73·0	78·5	—	74·5	92	6·9	19·95	—	26	4·7	38
Lagos, Nigeria ..	1013·4	+1·3	87	65	83·6	69·7	76·7	−2·0	75·2	86	7·3	8·46	—	19	3·6	30
Kaduna, Nigeria ..	1010·7	—	88	64	84·5	67·1	75·8	−0·1	70·9	81	6·7	4·77	−6·73	22	6·6	54
Chileka, Nyasaland	1018·6	+0·2	93	55	86·6	63·3	74·9	+2·4	60·4	45	0·9	0·00	−0·18	0	9·5	79
Lusaka, Rhodesia ..	1014·4	+0·5	94	53	89·1	59·4	74·3	+2·8	57·0	38	0·6	0·00	−0·04	0	10·0	83
Salisbury, Rhodesia	1016·9	+0·1	89	47	81·4	54·6	68·0	+2·2	53·8	39	0·3	0·00	−0·20	0	9·9	83
Cape Town	1019·6	+0·5	76	43	65·8	52·1	58·9	+1·0	50·6	72	3·7	2·48	+0·24	14	—	—
Palmietfontein, S. Africa	1018·2	—	87	39	78·1	49·0	63·5	—	50·5	50	1·0	0·79	—	3	10·0	—
Mauritius	1020·1	0·0	84	58	78·8	63·1	70·9	+0·8	62·1	59	4·3	1·40	0·00	18	8·2	68
Calcutta, Alipore Obsy.	1003·1	−1·4	95	74	90·2	79·0	84·6	+1·4	80·3	83	6·0	13·19	+3·18	21	5·2	42
Bombay	1005·7	−2·3	89	73	85·1	75·7	80·4	−0·5	77·2	89	6·6	49·01	+38·33	29	2·7	22
Madras	1005·3	−1·2	94	73	90·7	77·0	83·9	−1·3	75·7	75	6·4	6·74	+1·89	12	5·0	41
Colombo, Ceylon ..	1009·6	−0·3	87	74	85·7	78·1	81·9	+0·7	77·2	82	6·0	3·04	−1·72	18	6·3	52
Singapore	1009·8	0·0	91	73	87·3	75·6	81·5	+0·4	76·3	79	5·3	6·34	−0·45	15	6·2	51
Hongkong	1008·7	+0·4	90	74	86·6	77·0	81·8	+0·8	77·2	83	—	17·02	+7·33	17	7·0	57
Sydney, N.S.W. ..	1019·7	+3·6	81	45	66·4	52·4	59·4	+0·2	54·8	76	4·5	9·04	+6·18	19	5·6	47
Melbourne	1020·0	+4·2	78	33	63·0	43·1	53·1	−1·0	48·3	69	4·9	1·61	−0·83	17	6·5	55
Adelaide	1021·1	+3·6	81	39	66·5	47·0	56·7	−0·5	50·7	53	4·0	0·82	−1·26	8	6·8	58
Perth, W. Australia	1019·9	+1·9	80	39	68·5	48·4	58·5	+0·3	55·0	67	3·0	1·73	−1·69	12	8·2	69
Coolgardie	1019·4	+2·2	89	35	70·8	45·3	58·1	−0·6	49·1	45	3·5	0·58	−0·09	5	—	—
Brisbane	1019·8	+2·2	80	49	73·4	54·9	64·1	−1·1	57·5	64	3·3	2·07	+0·07	11	8·3	70
Hobart, Tasmania	1015·9	+4·9	74	33	61·1	40·4	50·7	−0·3	44·8	59	4·4	0·59	−1·48	11	6·5	55
Wellington, N.Z. ..	1015·3	+1·0	64	35	55·4	44·4	49·9	−0·2	47·4	77	5·1	2·01	−1·96	12	6·7	57
Suva, Fiji	1013·8	−0·5	85	64	78·2	70·0	74·1	−0·4	71·1	87	7·2	17·98	+10·29	29	2·1	17
Apia, Samoa ..	1012·4	+0·6	88	72	86·7	74·1	80·4	+1·5	77·2	79	4·8	7·53	+1·99	21	8·5	71
Kingston, Jamaica	1012·5	+0·3	93	72	89·4	74·9	82·1	+0·6	75·7	76	3·9	6·75	+2·72	9	6·9	56
Grenada, W. Indies																
Toronto	1017·1	−0·7	83	38	67·6	50·7	59·1	−1·2	50·8	88	6·1	3·42	+0·75	10	6·2	50
Winnipeg	1013·3	−0·5	84	25	64·9	42·8	53·9	+0·2	42·8	84	5·4	1·53	−0·69	8	6·3	50
St. John, N.B. ..	1016·3	−1·1	76	40	65·0	51·0	58·0	+2·1	53·8	88	7·8	8·11	+4·37	16	5·6	44
Victoria, B.C. ..	1016·0	−0·4	84	39	60·0	48·3	58·7	+2·6	49·5	89	3·6	0·69	−1·12	5	7·6	60

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VARIATION OF GEOSTROPHIC WIND WITH POTENTIAL TEMPERATURE IN THE HORIZONTAL AND IN THE VERTICAL, WITH APPLICATION TO VERTICAL CROSS-SECTION DIAGRAMS

By A. G. MATTHEWMAN, B.A.

Vertical cross-section diagrams of the atmosphere which display the isopleths of geostrophic-wind component perpendicular to the cross-sections are of considerable interest, particularly in studies of the jet stream (*e.g.* Palmén[1]*, Nagler[2], Hovmöller[3], Durst and Davis[4], Nyberg[5]).

The computations on which the construction of the isopleths are based, can become excessively laborious. The purpose of the present article is to derive a convenient graphical means of constructing and checking these isopleths. The same problem has been considered on somewhat different lines by Bleeker[6]. The merits of the present treatment are that it applies to Form 2815[†], it is reasonably quick and accurate, and certain reciprocal relations, which will be derived in this note, regarding the variation of geostrophic wind with potential temperature in the horizontal and in the vertical, are mutually helpful in constructing the detail in the neighbourhood of jet streams and of the tropopause.

Theory of the method.—The method is based on the geostrophic thermal-wind relation applied to dry-bulb (or more exactly, virtual) potential temperature. With the usual notation, the dry-bulb potential temperature θ is defined by

$$\theta = T\left(\frac{p_0}{p}\right)^{\frac{(\gamma-1)}{\gamma}}$$

and the virtual potential temperature θ' by

$$\theta' = T'\left(\frac{p_0}{p}\right)^{\frac{(\gamma-1)}{\gamma}} \qquad \text{.. (1)}$$

where T' is the virtual temperature, p_0 is some standard pressure, here taken, as usual, 1000 mb. and $\gamma = C_p/C_v$.

Take the horizontal direction from left to right in the plane of the vertical cross-section as the axis of x, and the vertical direction as the axis of z or p. The hydrostatic equation is

$$\left(\frac{\partial z}{\partial p}\right)_x = -\frac{1}{g\rho}$$

Substituting for ρ from the equation of state $p = R\rho T'$,

$$\left(\frac{\partial z}{\partial p}\right)_x = -\frac{RT'}{gp},$$

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[*] The index numbers refer to the list of references on p. 102.

[†] Meteorological Office, London, Form 2815. Vertical cross section of the atmosphere (large scale).

and for T' in this last equation from equation (1)

$$\left(\frac{\partial z}{\partial p}\right)_x = -\frac{R}{g}.\theta'.\frac{p^{-1/\gamma}}{p_o^{(1-1/\gamma)}} \qquad \text{.. (2)}$$

The geostrophic component v_J directed perpendicular to, and to the left of the axis of x is given by

$$v_J = \frac{g}{\lambda}\left(\frac{\partial z}{\partial x}\right)_p \qquad \text{.. (3)}$$

By (3),

$$\left(\frac{\partial v_J}{\partial p}\right)_x = \left[\frac{g}{\lambda}.\frac{\partial}{\partial p}.\left(\frac{\partial z}{\partial x}\right)_p\right]_x$$

$$= \frac{g}{\lambda}\left[\frac{\partial}{\partial x}.\left(\frac{\partial z}{\partial p}\right)_x\right]_p$$

which by (2)

$$= \frac{g}{\lambda}\left[-\frac{R}{g}.\frac{p^{-1/\gamma}}{p_o^{(1-1/\gamma)}}\left(\frac{\partial \theta'}{\partial x}\right)_p\right]$$

Thus

$$\left(\frac{\partial v_J}{\partial p}\right)_x = -\frac{R}{\lambda}.\frac{p^{-1/\gamma}}{p_o^{(1-1/\gamma)}}\left(\frac{\partial \theta'}{\partial x}\right)_p \qquad \text{.. (4)}$$

Now

$$\left(\frac{\partial v_J}{\partial \theta'}\right)_x = \frac{\left(\frac{\partial v_J}{\partial p}\right)_x}{\left(\frac{\partial \theta'}{\partial p}\right)_x}.$$

Hence by (4),

$$\left(\frac{\partial v_J}{\partial \theta'}\right)_x = -\frac{R}{\lambda}.\frac{p^{-1/\gamma}}{p_o^{(1-1/\gamma)}}\,\frac{\left(\frac{\partial \theta'}{\partial x}\right)_p}{\left(\frac{\partial \theta'}{\partial p}\right)_x}$$

$$= +\frac{R}{\lambda}.\frac{p^{-1/\gamma}}{p_o^{(1-1/\gamma)}}\left(\frac{\partial p}{\partial x}\right)_{\theta'}$$

$$= \frac{1}{\lambda}.\frac{R}{(1-\frac{1}{\gamma})}.\frac{1}{p_o^{(1-1/\gamma)}}\left\{\frac{\partial}{\partial x}\left(p^{1-1/\gamma}\right)\right\}_{\theta'} \qquad \text{.. (5)}$$

Now define $\mathcal{Z}$ such that

$$-a\mathcal{Z} + b = p^{(1-1/\gamma)}$$

where a, b are constants, a positive, and write

$$k = a\frac{R}{(1-\frac{1}{\gamma})}\cdot\frac{1}{p_o^{(1-1/\gamma)}}$$

another constant, also positive.

Then (5) may be written

$$\left(\frac{\partial v_J}{\partial \theta'}\right)_x = -\frac{k}{\lambda}\left(\frac{\partial \mathcal{Z}}{\partial x}\right)_{\theta'} \qquad \text{.. (6)}$$

Now

$$\left(\frac{\partial v_J}{\partial \theta'}\right)_p.\left(\frac{\partial \theta'}{\partial x}\right)_p = \left(\frac{\partial v_J}{\partial x}\right)_p$$

and

$$\left(\frac{\partial v_J}{\partial \theta'}\right)_x.\left(\frac{\partial \theta'}{\partial p}\right)_x = \left(\frac{\partial v_J}{\partial p}\right)_x.$$

Hence
$$\frac{\left(\frac{\partial v_J}{\partial \theta'}\right)_p}{\left(\frac{\partial v_J}{\partial \theta'}\right)_x} = \frac{\left(\frac{\partial v_J}{\partial x}\right)_p}{\left(\frac{\partial v_J}{\partial x}\right)_x} \Bigg/ \frac{\left(\frac{\partial \theta'}{\partial x}\right)_p}{\left(\frac{\partial \theta'}{\partial p}\right)_x}$$

$$= \frac{\left(\frac{\partial p}{\partial x}\right)_{v_j}}{\left(\frac{\partial p}{\partial x}\right)_{\theta'}}$$

which, from the definition of Z above,

$$= \frac{\left(\frac{\partial Z}{\partial x}\right)_{v_j}}{\left(\frac{\partial z}{\partial x}\right)_{\theta'}} \qquad \ldots (7)$$

From (6) and (7) it follows that

$$\left(\frac{\partial v_J}{\partial \theta'}\right)_p = -\frac{k}{\lambda}\left(\frac{\partial Z}{\partial x}\right)_{v_j} \qquad \ldots (8)$$

The reciprocal relations.—Equations (6) and (8) state that, on a vertical cross-section diagram with suitable ordinate Z, in a given latitude, the rate of change of v_J (the geostrophic component perpendicular to the cross-section) with virtual potential temperature θ' (i) along the vertical is proportional to the slope of the isopleths of θ' and (ii) along the horizontal is proportional to the slope of the isopleths of v_J. Moreover, the factors of proportionality in (i) and (ii) are the same. It is these relations which form the basis of the graphical method here proposed.

Vertical cross-section diagrams could be prepared, with ordinate z as defined, for the direct application of these relations. However, the diagram generally used in the British meteorological service (Form 2815) is one in which the linear ordinate is the I.C.A.N. height. Since the I.C.A.N.-height scale is very nearly a linear function of Z, the reciprocal relations can be applied without difficulty to Form 2815.

A scale has therefore been prepared, which by measuring the slopes of the isopleths of θ' and v_J gives directly the change in v_J, in knots per 10°F. of potential temperature, in the horizontal and vertical directions. This scale will now be described.

Vertical cross-section scale.—The scale, which is transparent, fits over Form 2815 (see Fig. 1 (*a*)). The scale of the abscissa of the cross-section is taken to correspond to a conical-orthomorphic projection, scale $1 : 7{\cdot}5 \times 10^6$, standard parallels 30° and 60°.

The 1013-mb. line (I.C.A.N.-height zero) on the scale coincides with the corresponding line marked on Form 2815.

The scale is marked with a vertical line on the left and a series of vertical lines each for the appropriate latitude (30° to 70°) on the right.

These vertical lines carry unit markings of Z' from -3 to $+83$, their relation to the I.C.A.N.-height scale of h, say, in kilometres, being given in the following table:—

TABLE I

Z'	0	5	10	15	20	25	30	35	40
					kilometres				
I.C.A.N. height	0	0·75	1·49	2·25	3·00	3·77	4·55	5·33	6·13

Z'	45	50	55	60	65	70	75	80
				kilometres				
I.C.A.N. height	6·92	7·73	8·54	9·38	10·21	11·04	11·92	12·83

On the scale, the distance *d* say, in centimetres between the left-hand vertical line and the vertical line corresponding to various latitudes from 30° to 70° is given in the following table.

TABLE II

			degrees		
Latitude ø	30	40	50	60	70
			centimetres		
Distance *d*	9·95	7·51	6·28	5·74	5·73

For a horizontal scale of 1 : 15 × 10^6, values of *d* are divided by 2. A copy of the cross-section is shown in Fig. 1.

Use of the scale.—On the cross-section Form 2815, the isopleths of potential temperature are drawn at 5°F. or 10°F. intervals.

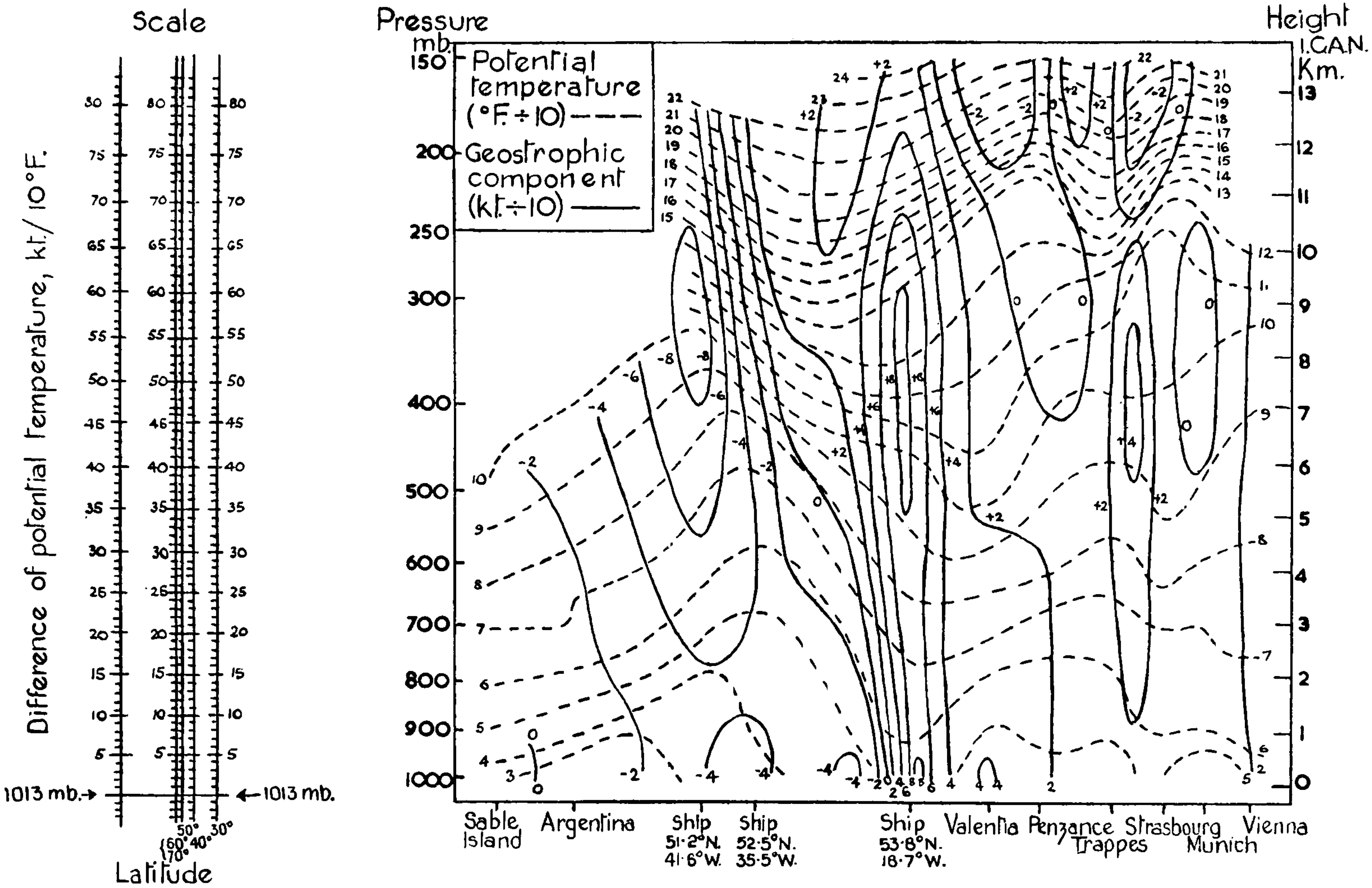
The values of vj, the geostrophic wind component at right angles to the cross-section (directed into the paper) at some low level, *e.g.* 1000 mb., measured on the appropriate synoptic chart at sufficient points, are entered along the line of the cross-section. Then the scale is placed over the cross-section, with the 1013-mb. lines coinciding. A ruler or straight edge is placed tangential to the isopleths of potential temperature at any point of the scale, and where the ruler crosses the vertical lines of the scale the value in units on the vertical line on the left is subtracted from the value on the vertical line on the right for the appropriate latitude. This subtraction gives the decrease in knots of the geostrophic component vj along the vertical per 10°F. increase in potential temperature.

Starting from a known value of vj (say at 1000 mb.) the values of vj in a series of steps of 10°F. potential temperature along any vertical of the cross-section can thus be obtained, and a set of isopleths of vj sketched in.

The same scale can now be applied to these provisional isopleths of vj. Where a ruler placed across the scale tangential to an isopleth of vj crosses the vertical lines of the scale, the value in units on the vertical line on the left is subtracted from the value on the vertical line on the right for the appropriate latitude. This subtraction gives the decrease in knots of the geostrophic component vj along the horizontal per 10°F. increase in potential temperature. If necessary the isopleths of vj can be adjusted until consistency is obtained.

Example.—Fig. 1 (*b*) shows a vertical cross-section from Sable Island to Vienna on March 31, 1948, at 0300 G.M.T. A wave depression at that time was centred (at mean sea level) about 70 miles north-west of the ship at 53·8°N. 18·7°W. with central pressure about 965 mb., and was deepening and moving east by north.

On the cross-section, isopleths of dry-bulb potential temperature have been drawn from the reported values, at intervals of 10°F.



(*a*) Vertical cross-section scale

(*b*) Vertical cross-section 0300 G.M.T., March 31, 1948

FIG. I

Isopleths of v_J, the geostrophic wind component perpendicular to the cross-section (directed into the paper) are drawn at intervals of 20 kt. from (i) the values of v_J at mean sea level at points along the cross-section, and (ii) the variation of v_J with steps of 10°F. potential temperature along the vertical and horizontal axes by use of the scale described above (with horizontal scale here $1 : 15 \times 10^6$).

The author is indebted to Dr. Sutcliffe for criticisms and to Mr. Sawyer for the checking of the computations involved in constructing the scale.

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METHOD FOR FORECASTING THE TIME OF CLEARANCE OF RADIATION FOG OR LOW STRATUS

By G. J. JEFFERSON, M.Sc.

Assuming that the temperature required to clear fog or low stratus can be estimated by methods already evolved, a graphical method is devised of deciding when the required temperature will be reached on mornings when no cloud impedes the solar-radiation beam. Time-temperature curves are forecast and drawn for each occasion starting from the forecast clear-morning curve between sunrise and the time of diurnal maximum temperature which is modified according to the expected delay factor due to absorption and reflection of the solar radiation by the fog or stratus layer.

To forecast the time of clearance of fog or low stratus it is the normal practice for an estimate to be made of a screen temperature which is sufficient to clear the fog or cloud on the assumption of a convective layer with approximately a dry-adiabatic lapse rate. With this temperature estimated it is necessary to decide if and when it will be reached taking account of the season of the year, the density of the fog or cloud, and any screening by higher layers of cloud.

In another paper[1]* Gold's method[2] of forecasting maximum day temperatures was empirically extended for Northolt to give an estimated curve of temperature rise with time after sunrise in cases of clear sky. This curve is shown by the continuous line in Fig. 1.

The basic idea of the earlier article is that the heat energy absorbed by the surface layers of the atmosphere up to a certain time after dawn will be roughly constant at a given season of the year and will be represented by a constant area on the tephigram.

When the incoming solar radiation is interrupted by fog or cloud the rate of heating is reduced, and it was thought that, by introducing a form of " delay factor " representing the reduction in the rate of heating and estimated from the thickness of the fog or cloud, it might be possible to estimate an adjusted heating curve taking a clear-sky curve for the season as a basis.

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*The index numbers refer to the list of references on p. 109.

Let us assume that up to any given time after sunrise the amount of heat added to the lowest layers of air is, with fog conditions, 50 per cent. of what it would have been with a clear sky. Assuming the delay factor to be constant during the heating period it will take twice as long from sunrise for a given temperature rise to take place as on a clear day.

We can then draw a corrected forecast-temperature curve shown by the broken line on Fig. 1. This can be drawn making BC = AB for any given temperature. When the temperature reaches T_c, the temperature required to clear the fog, the time of clearance is read from the abscissa at H. After T_c has been passed the curve rises more steeply and more in line with clear-day characteristics, although if the clearance is late the maximum temperature reached is likely to be below what it would have been had there been no fog or stratus. If T_c has not been reached by the time of maximum temperature, M, then one would forecast no clearance of the fog or stratus.

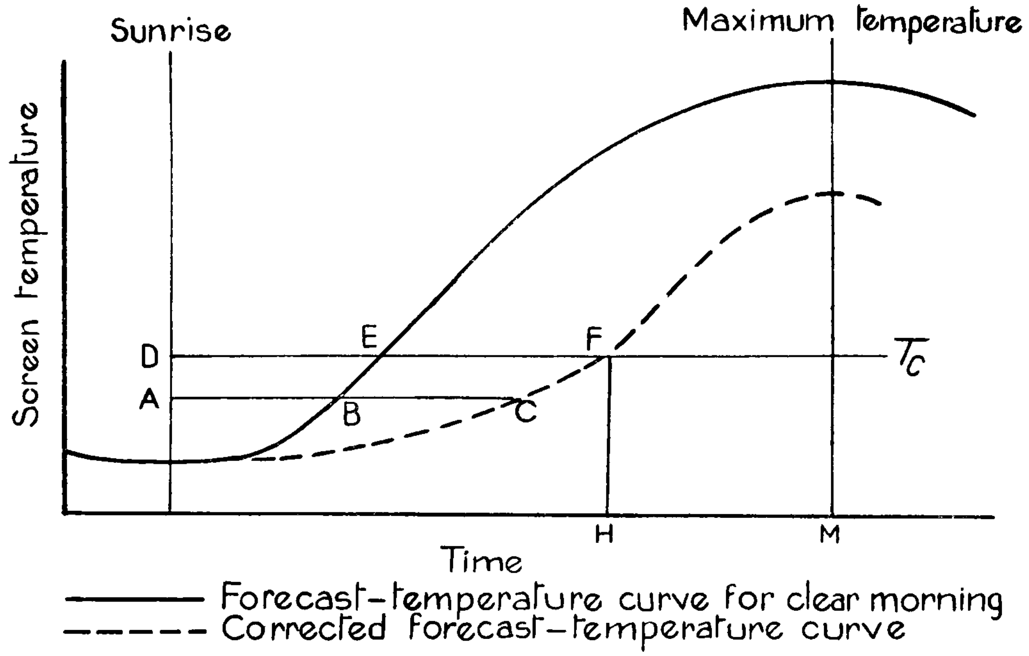

FIG. 1—CORRECTED FORECAST-TEMPERATURE CURVE

Tc is the temperature required to clear fog or low stratus by morning solar radiation

In the same way a corrected curve can be drawn for any other delay factor making AB/AC equal to the delay factor at every temperature below T_c.

In practice this can be done conveniently by putting a graduated scale along the line ABC and marking a number of points C which are afterwards joined by a smooth curve. If T_c is not reached by time M then the maximum temperature to be expected can be forecast.

The theory of the problem is very complicated, but an order of magnitude may be obtained by assuming that the rate of heating of the surface layers (as represented by area on the tephigram) is reduced in proportion to the short-wave solar radiation which penetrates the fog or cloud. The use of this in practice demands a transmission factor for use on each separate occasion.

To derive some idea of what it would be, use has first been made of figures given by Hewson[3] who provided transmission values for fog, assuming a droplet radius of 2×10^{-3} cm., and cloud, assuming a droplet radius of 5×10^{-4} cm. These figures are given for three values of the sun's zenith distance. Since the period for which the value is most important is from sunrise to about midday, the values for 78·7° were used.

Hewson's values were plotted on a graph of thickness, in metres, against density of water, in grams per cubic metre, and curves of equal transmission percentage drawn as shown in Fig. 2. Some estimate of the water content can be made, especially in the case of fog, from the humidity mixing ratio, sunrise temperature and probable midday dew point of the air. The depth of fog, however, is difficult to estimate with any accuracy, although a rough idea can be formed by the amount of light transmitted and the time when the fog formed. Any observations by aircraft can, of course, be used with advantage. It is apparent that for practical forecasting the number of variables, whose values can at best be only estimated, is too great for the transmission value to be accurately decided without more data than is available in a normal forecasting office.

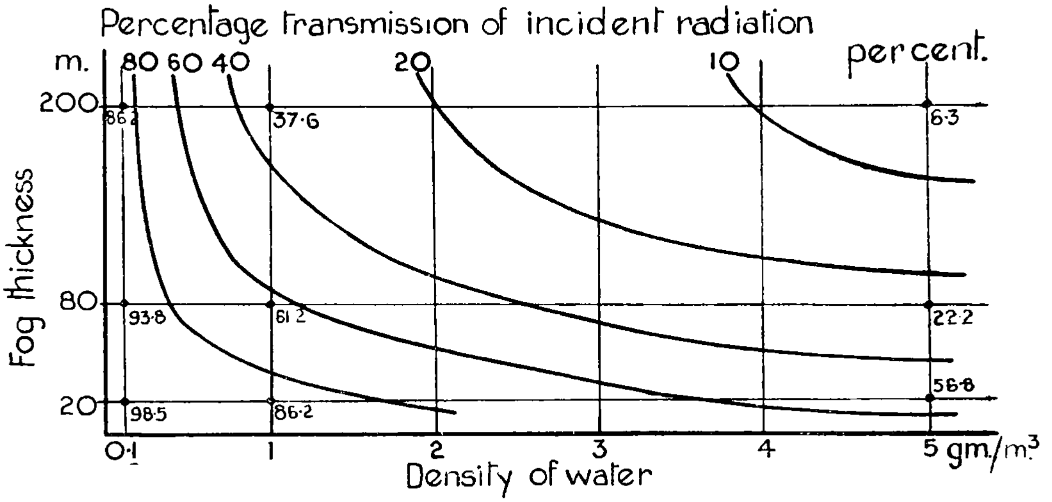

FIG. 2—PERCENTAGE TRANSMISSION OF INCIDENT RADIATION THROUGH LAYERS OF FOG

Based on values by Hewson for sun's zenith distance 78·7°

To overcome this difficulty a start was made using arbitrary values. Hewson gives 1 gm./m.^{3} for moderate fog and 5 gm./m.^{3} for very dense fog. Values of 1·5–2 gm./m.^{3} which appeared to be a possible value for thick morning fog and thickness of 100–150 m. (300–500 ft.) were used. These figures give transmission values of the order of 30–50 per cent. which give the sort of curve which would be expected although similar percentages of transmission can be obtained from Hewson's figures by taking 0·8–1·5 gm./m.^{3} water content and a thickness of 150–200 m. (500–600 ft.).

Using this as a basis, forecast curves were drawn on a number of mornings when it was known that there was clear sky above the layer of radiation fog. Transmission values of 30 per cent. were used when the fog was dense and of some hours' duration, but nearer 50 per cent. when it was thin and of recent formation. The actual temperatures which were observed are also plotted on the examples included with this article which are all copied from diagrams used to make actual forecasts.

It can be seen that generally speaking the curves of actual temperatures do appear to justify the percentages chosen. In some cases it was found possible to issue an amended forecast of the expected clearance time when the rate of rise of temperature in the first few hourly periods after sunrise enabled a revised delay factor to be estimated.

Such a case occurred on March 4, 1948, at Gatow, as shown on the accompanying example, Fig. 4, where an original forecast of clearance at 0930 G.M.T. based on a delay factor of 40 per cent. was amended to 25 per cent., in this way giving a clearance about 1200 G.M.T. which it will be seen was much nearer the truth as no real clearance actually occurred all day. On October 5, 1947, in the curves for Northolt, an original forecast of 0930 G.M.T. based on 50 per cent. delay factor is shown, while the curve of actual temperature gave 40 per cent. and a clearance time about one hour later.

Of the nine examples given seven are in the months of March and October, and there is reason to think that the spring and autumn seasons are the times of year when the method is likely to prove most useful and effective. In the summer months morning fog is rare, while in the winter months the amount of heat energy absorbed from insolation by the surface layers and accompanying rise of temperature are small, and when reduced further by a fog layer will tend to be masked by other local variations. This can be seen from the other two examples given, particularly from that of November 29, 1948, when temperature fell steadily throughout the heating period due to the slow but steady advection of colder air. Furthermore, it is on mornings in spring and autumn, when the fog clearance may be expected to be fairly sudden, that an accurate forecast of clearance time is of most value for aviation.

The remaining seven examples have been analysed and the results shown in the accompanying table. The delay factor, which the actual temperature curve shows as compared with the forecast clear-morning curve, has been computed for periods of two to six hours from sunrise.

Place	Date	2*				3*				4*			
		Delay factor	Visibility	Cloud Amount	Cloud Height	Delay factor	Visibility	Cloud Amount	Cloud Height	Delay factor	Visibility	Cloud Amount	Cloud Height
		%	yd.	tenths	ft.	%	yd.	tenths	ft.	%	yd.	tenths	ft.
Northolt	5.10.47	26	100	sky obscured		36	200	sky obscured		37	60	sky obscured	
Gatow	13.10.47	..	..	..	..	..	..	..	..	..	..	..	..
Northolt	21.10.47	..	..	..	..	..	..	..	..	35	300	0	0
Gatow	6.12.47	..	..	..	..	..	..	..	..	52	600	10	200
Gatow	3. 3.48	46	200	0	0	37	200	0	0	34	700	0	0
Gatow	4. 3.48	20	100	sky obscured		22	200	sky obscured		26	400	0	0
Gatow	5. 3.48	44	100	0	0	34	200	0	0	30	700	0	0
Gatow	7. 3.48	40	100	0	0	34	700	0	0	34	900	0	0

Place	Date	5*				— 6*			
		Delay factor	Visibility	Cloud Amount	Cloud Height	—la— Dey factor	Visibility	Cloud Amount	Cloud Height
		%	yd.	tenths	ft.	%	yd.	tenths	ft.
Northolt	5.10.47	49	60	0	0	..	..	..	..
Gatow	13.10.47	41	800	10	600	45	3,500	10	600
Northolt	21.10.47	..	..	..	..	..	..	..	..
Gatow	6.12.47	49	900	10	200	42	400	sky obscured	
Gatow	3. 3.48	38	1,200	0	0	..	..	..	..
Gatow	4. 3.48	24	900	0	0	22	600	0	0
Gatow	5. 3.48	32	800	0	0	34	700	0	0
Gatow	7. 3.48	..	..	..	..	..	..	..	..

*Hours from sunrise.

The results suggest that in most cases of morning fog in spring and autumn a factor of about 35 per cent. is correct for the periods from sunrise to beyond three hours until the clearance time approaches. The temperature rise expected

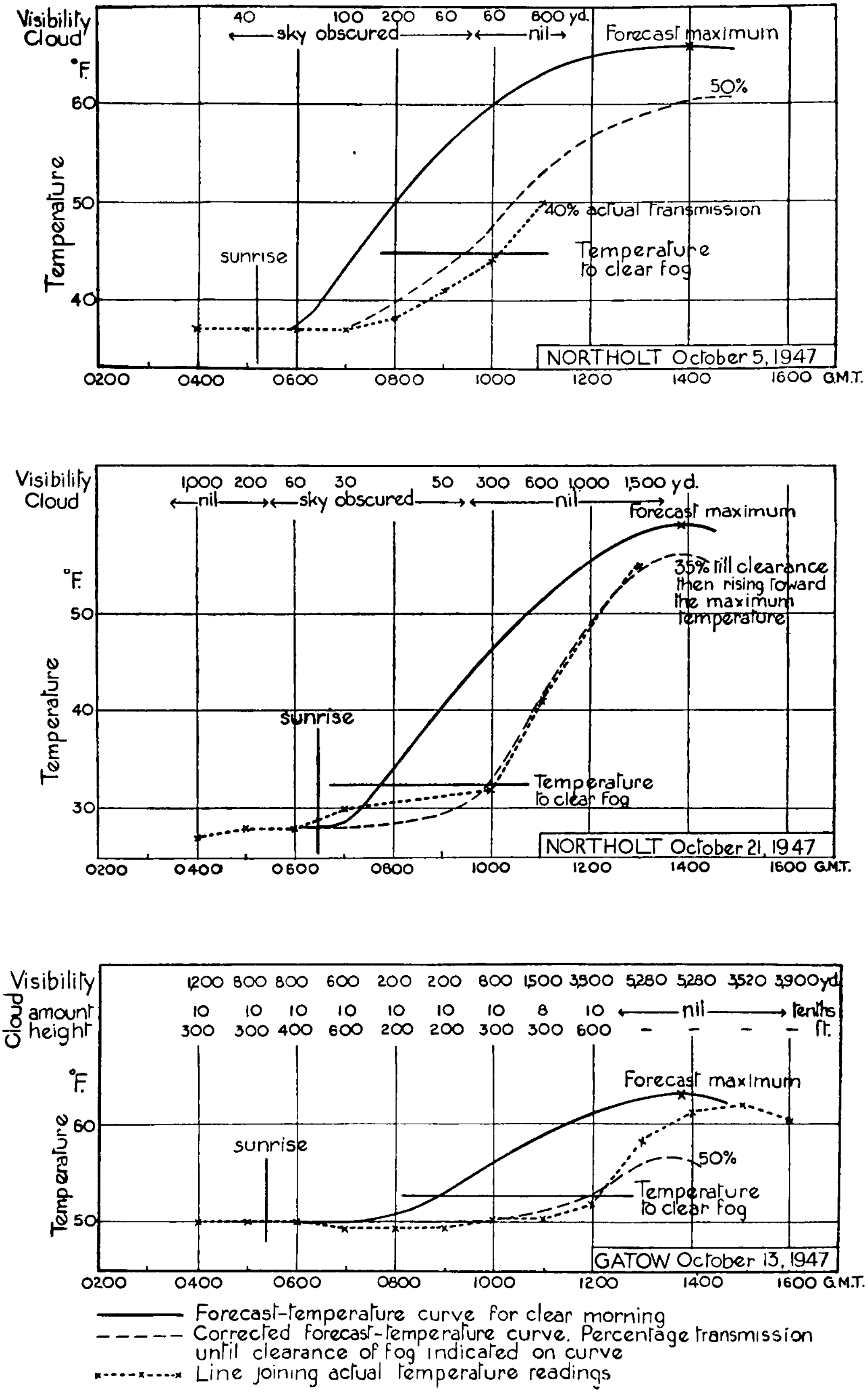

FIG. 3—EXAMPLES OF CORRECTED FORECAST-TEMPERATURE CURVES

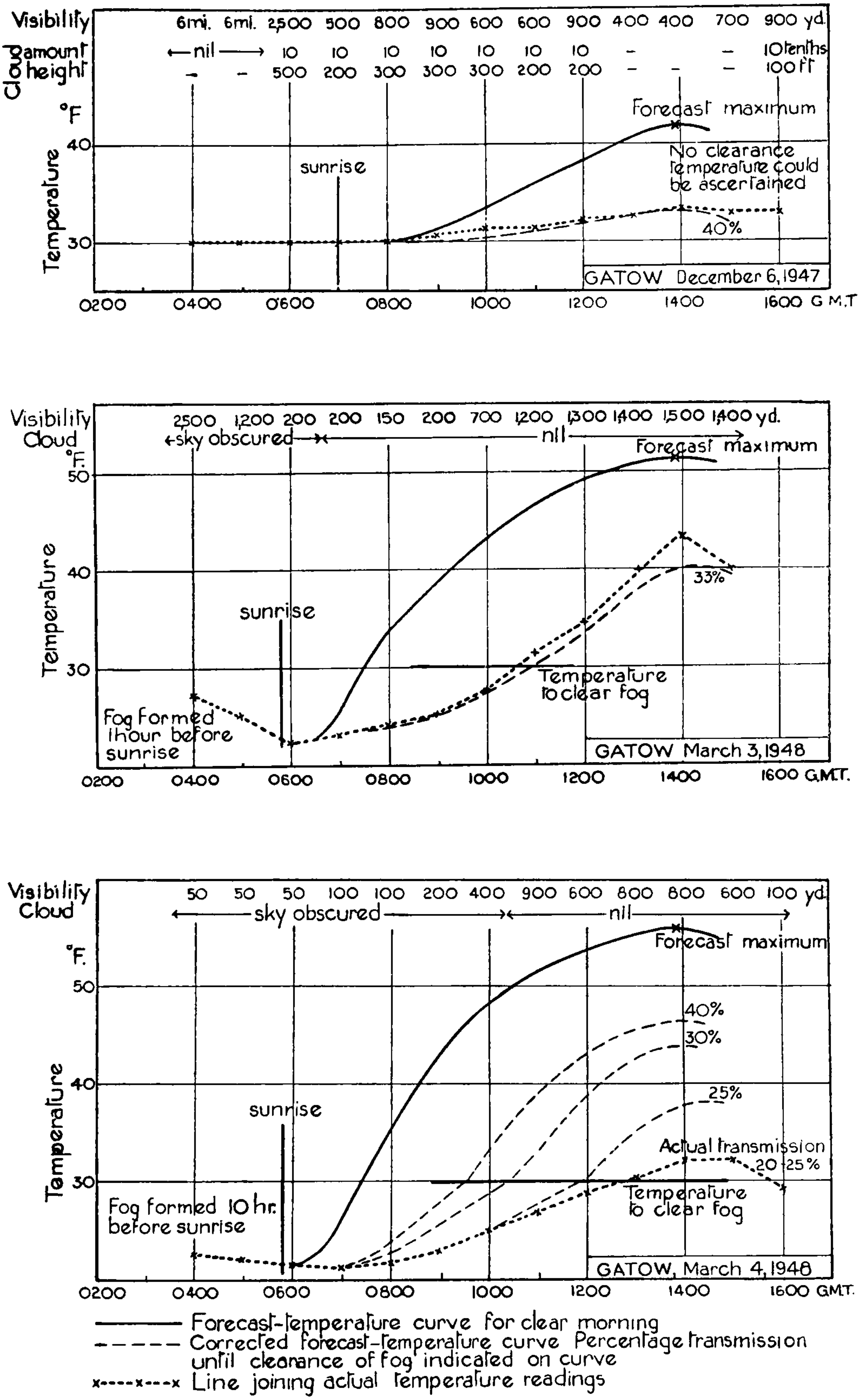

FIG. 4—EXAMPLES OF CORRECTED FORECAST-TEMPERATURE CURVES

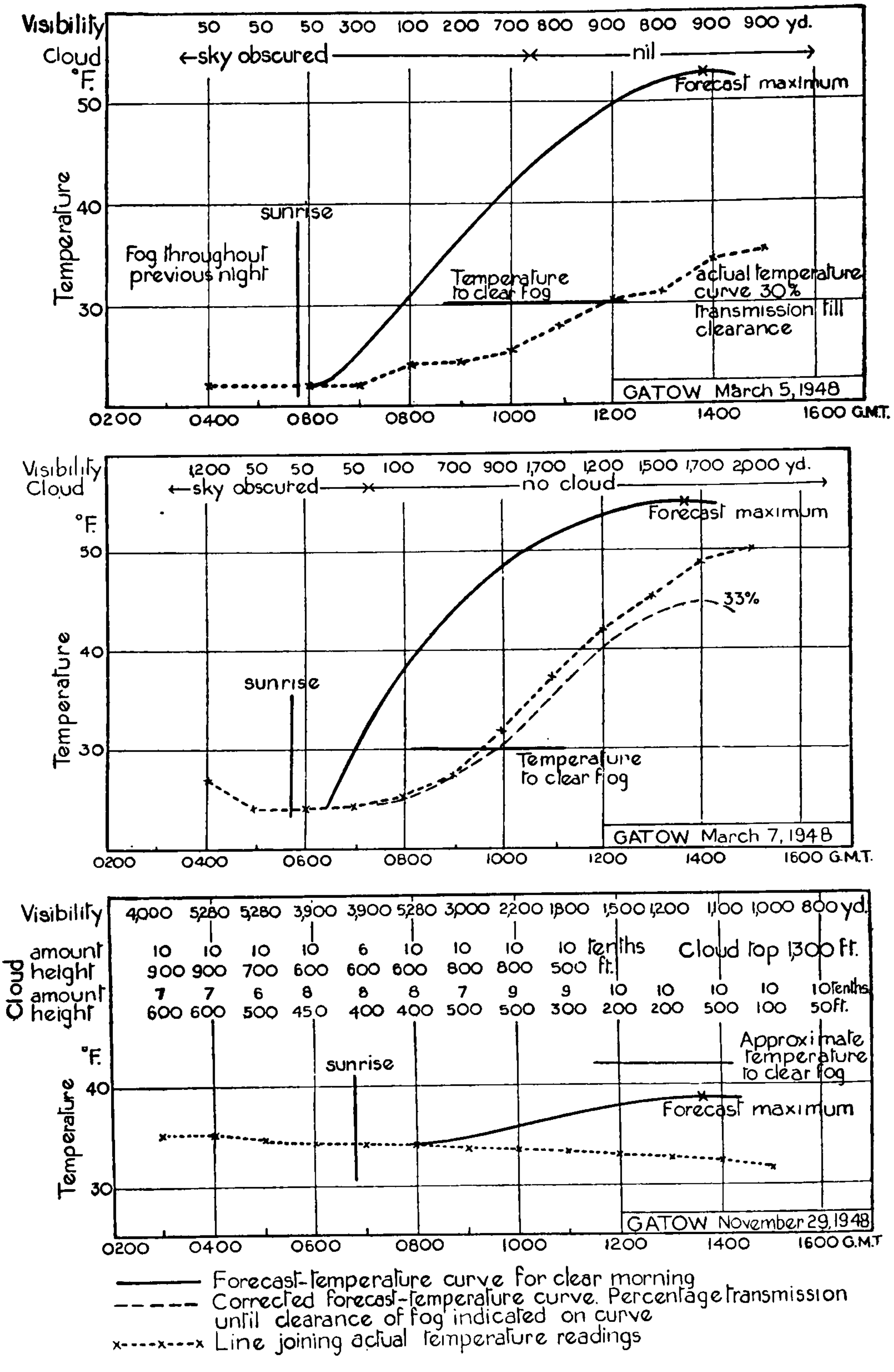

FIG. 5.—EXAMPLES OF CORRECTED FORECAST-TEMPERATURE CURVES

The curve of actual temperature recordings at Gatow on November 29, 1948, appears to suggest there was advection of colder surface air during the day. A steep inversion was present above the cloud layer with a temperature of 40°F. from 950 to 850 mb. An aircraft report gave the top of the cloud layer as 1,300 ft. between 1400 and 1500 G.M.T.

in a period shorter than three hours is too small for any accurate factor to be ascertained. On occasions of thicker fog as exemplified on March 4, 1948, when the fog formed some ten hours before sunrise 25 per cent. would appear a better figure. A rough classification can thus be made for typical morning fogs in autumn and spring:—

(*a*) thin and shallow, delay factor 35 per cent.
(*b*) thick and deep, delay factor 25 per cent.

I wish to acknowledge advice given by Dr. Sutcliffe in the preparation of this and the earlier[1] article.

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RADAR WEATHER ECHOES

By R. F. JONES, B.A.

Part I

The fact that radar echoes are received from certain types of weather phenomena, when the radar wave-length is sufficiently small, is now well known, and most readers will be familiar with the photographs of such echoes which have appeared from time to time in various publications. The most usual type of presentation used in these photographs has been that provided by the Plan Position Indicator or P.P.I., which gives the projection of the radar echoes received from the surrounding atmosphere on the (almost) horizontal plane through the radar set. The area covered extends usually to a radius of about 60 miles from the radar set although, exceptionally, greater ranges have been displayed. Less frequently, various types of presentation have been used which show a cross-section of a particular echo in the vertical plane along a certain bearing from the radar set. The wave-length used in all cases has been either 10 cm. or 3 cm.

It has been well established that the weather echo is caused by the back-scattering of the radio energy from the solid and liquid particles in the atmosphere, *e.g.* ice crystals, snow-flakes, cloud droplets and raindrops. In the case of spherical liquid drops it has been shown theoretically[1]*, and borne out by experiment, that the amount of energy back-scattered to the radar receiver is proportional to the expression ΣND^6, where N is the number of drops of diameter D per unit volume. For solid particles the echo intensity depends primarily on the mass of the ice crystal or snow-flake and the precipitation rate[1].

Clearly for any radar receiver there is a minimum receivable power which can be detected and there is, therefore, for rainfall a value of the expression ΣND^6 below which no echo will be detected, this minimum value depending on the efficiency of the receiver and the wave-length employed. For most, if not all, of the 10-cm. sets used, and probably for the 3-cm. sets also, it is highly probable that this minimum value of ΣND^6 is such that, at ranges greater than 10 miles, the echo comes from water-drops of raindrop size, *i.e.* the echo received is from precipitation although this precipitation may not always reach the ground, *e.g.* in strong vertical currents it is possible that drops of raindrop size may be suspended or moving upwards in the vertical current, or on another occasion with high-level precipitation the drops may evaporate before reaching the ground. In the case of snow there will likewise be a minimum size of snow crystal or snow-flake or minimum value of precipitation rate below which no radar echo will be received. At the moment of melting of the ice crystal the position is more complex, but it has been shown[1] that an enhancement of the echo is likely to occur at this time and the occurrence of a " bright band " of echo close to the freezing level in conditions of weak vertical currents has frequently been observed.

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*The index numbers refer to the list of references on p. 112.

For the full theory of radar echoes from precipitation the reader is referred to a paper by Ryde[1] while the interpretation of various types of weather echo on the basis of this theory has been discussed in a report to the Meteorological Research Committee by the writer[2].

For our purposes it can be accepted that in a particular weather situation the radar echoes seen do not come from the whole volume of the clouds present but only from those parts of the clouds, and the volume beneath them, which contain (i) raindrops of a sufficient size and concentration, or (ii) individual ice crystals of a sufficient size and concentration, or (iii) snow-flakes formed from an aggregate of ice crystals of a sufficient concentration.

For rather more than two years weather echoes have been observed and photographed, using radar sets having a wave-length of 10 cm., at the Meteorological Office radar station at East Hill (near Dunstable). The photographs are principally from two different types of presentation, the P.P.I. presentation mentioned above and the Height-Range Tube (H.R.T.) presentation which gives the range and height of the observed echo directly and hence the vertical section through a weather echo when observed on a fixed bearing. There is now a large collection of photographs of weather echoes on these two presentations covering almost every type of weather situation which affects the Midlands of England and which are probably typical of similar situations elsewhere in the temperate zone. In the following sections are given examples of the radar echoes in the horizontal and vertical sections in various types of weather situation.

Cold front by radar.—The typical P.P.I. picture of a cold front (see photograph (*a*) of series of photographs between p. 112 and p. 113) shows it as a long and generally very narrow band of echo stretching across the face of the display tube and visible on occasions to ranges greater than 40 miles. The band of echo is rarely quite continuous, although the cloud associated with the front is almost certainly so, but is formed of a large number of small cores of echo of quite high intensity very close together and even at short ranges the cellular structure remains.

When seen in the vertical cross-section (photographs (*b*) and (*c*)) the cellular structure is again demonstrated, the cores of high intensity being associated with strong vertical columns of echo. The probability is that these cores are associated with relatively strong vertical currents, compared with those existing in the remainder of the frontal cloud, and marked turbulence, and probably come from cumulonimbus clouds embedded in the frontal-cloud system, while the spaces between them which are clear of echo are probably areas of down currents.

The whole frontal-cloud system does not contain radar-reflecting particles of sufficient size and concentration to give a radar echo with our equipment, and the responses obtained show that on a large number of occasions the moderate to heavy rain of the front must be confined to a very narrow belt, only a few miles wide, at the leading edge of the front.

Exceptionally, the precipitation area associated with the front, as shown by the radar, may be much wider than usual (photograph (*d*)) but even on these occasions the heaviest precipitation and probably the strongest vertical currents and turbulence are confined to a narrow belt as shown by the vertical cross-section on the radar in such cases (photographs (*e*) and (*f*)). In these cases behind the strong vertical columns at the leading edge of the front the vertical cross-section shows a mass of echo with a level and diffuse top. This echo is almost certainly from large ice crystals or snow-flakes in the altostratus sheet behind the surface position of the front, and the level and diffuse top is interpreted as evidence of widespread but weak upward currents and little turbulence.

The picture of the cold front as interpreted from the radar evidence is thus in keeping with the generally accepted idea of the cold front (see, for example, " Meteorology for Aviators ", p. 182[3]) with the exception that, in the Midlands of this country at least, the part of the cold front which has cumulonimbus characteristics is confined to a narrow belt of the order of 5–10 miles in width. Further details of the photographic illustrations are given below:—

Photograph (*a*). This P.P.I. photograph was taken at 1241 G.M.T. on November 12, 1947. The circular markers are at 5-mile intervals (the first complete circle visible being 10 miles from the station) while the radial lines are azimuth indicators at 20° intervals, the brightest one being at magnetic north. The echoes inside the 10-mile circle are permanent echoes from the high ground in the neighbourhood of the station and the short lines of echoes on about 270° and 290° from 10–15 miles are also permanent echoes. The belt of echoes associated with the cold front is some 85 miles long, but is nowhere wider than about 2–3 miles.

Photograph (*b*). This is an H.R.T. photograph taken at 1108 G.M.T. on August 25, 1948, on a bearing of 45° true, looking along a cold front at the moment when the front was passing over the station. Echoes from the front are visible to a range of about 35 miles in this direction and the tendency for the echo to divide into separate columns of echo is noticeable.

Photograph (*c*). This H.R.T. photograph was also taken on August 25, 1948, on a bearing of 307° true at 1029 G.M.T. as the cold front approached the station, and gives a section of the front approximately perpendicular to the line of the front and demonstrates the narrow width and column structure of the echo in this direction. The high-level response at 20,000 to 25,000 ft. is presumably from large ice crystals in the upper cloud of the front which decrease in size by evaporation in falling through a drier layer below 20,000 ft. with a consequent disappearance of the weather echo. The furthest echo at about 60 miles range is from a cumulonimbus which has developed in the cold air behind the front.

Photograph (*d*). This P.P.I. photograph was taken at 1051 G.M.T. on September 16, 1947. The range markers are not shown in their entirety but appear as spots at 5-mile intervals on the 20° azimuth indicators. The responses within 10 miles are (as in photograph (*a*)) from permanent echoes. The belt of echo nearest to the station is of greater intensity than the remainder, and, as shown in photograph (*e*), is probably associated with a narrow line of cumulonimbus clouds at the surface position of the front.

Photograph (*e*). This photograph, taken at 1044 G.M.T., shows the vertical section through the cold front of photograph (*d*) on a bearing of 255° magnetic. The cumulonimbus development in the front, as indicated by the tendency to column structure in the echo, is confined to a depth of less than 10 miles.

Photograph (*f*). This photograph was taken at 0738 G.M.T. on April 22, 1947, on a bearing of 69° true, some time after a cold front had passed through the station. The responses at 43–48 miles, although considerably attenuated due to the range at which they were viewed, show signs of column structure and were received from the surface position of the cold front. The remaining echo is associated with the altostratus sheet behind the front which was just clearing the station at the time of the photograph. There was no indication in the neighbourhood of the station of rain reaching the ground, and it is thought that the responses at ranges up to 15 miles at least were from large ice crystals or snow-flakes at 10,000–15,000 ft. which evaporated in the drier air beneath the frontal surface and completely vanished before reaching the ground, the ice crystals having already become too small to give a radar echo by the time they had fallen below 10,000 ft. Nearer to the surface cold front, with a decreasing cloud height and less depth of drier air, the height of the base of the radar echo also decreases.

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METEOROLOGICAL OFFICE DISCUSSION

The discussion on Monday, February 6, 1950, took the form of a symposium on the measurement of visibility. The opening speaker was Mr. G. J. W. Oddie.

Definitions and their consequences.—For meteorological purposes daylight visibility is defined as the distance at which dark objects, seen against the horizon sky as background, are just distinguishable for what they are. The objects selected should, if possible, subtend an angle of more than ½° in width and height (*i.e.* 46 ft. at one mile) and not more than 5° in width. Visibility at night is defined as the distance at which standard daylight objects would be just distinguishable if it were daylight and the atmospheric transparency were unchanged.

Daylight visibility observations are of direct use in many practical problems of seeing but night visibility observations require conversion, usually to the visual range of lights of specified candle power.

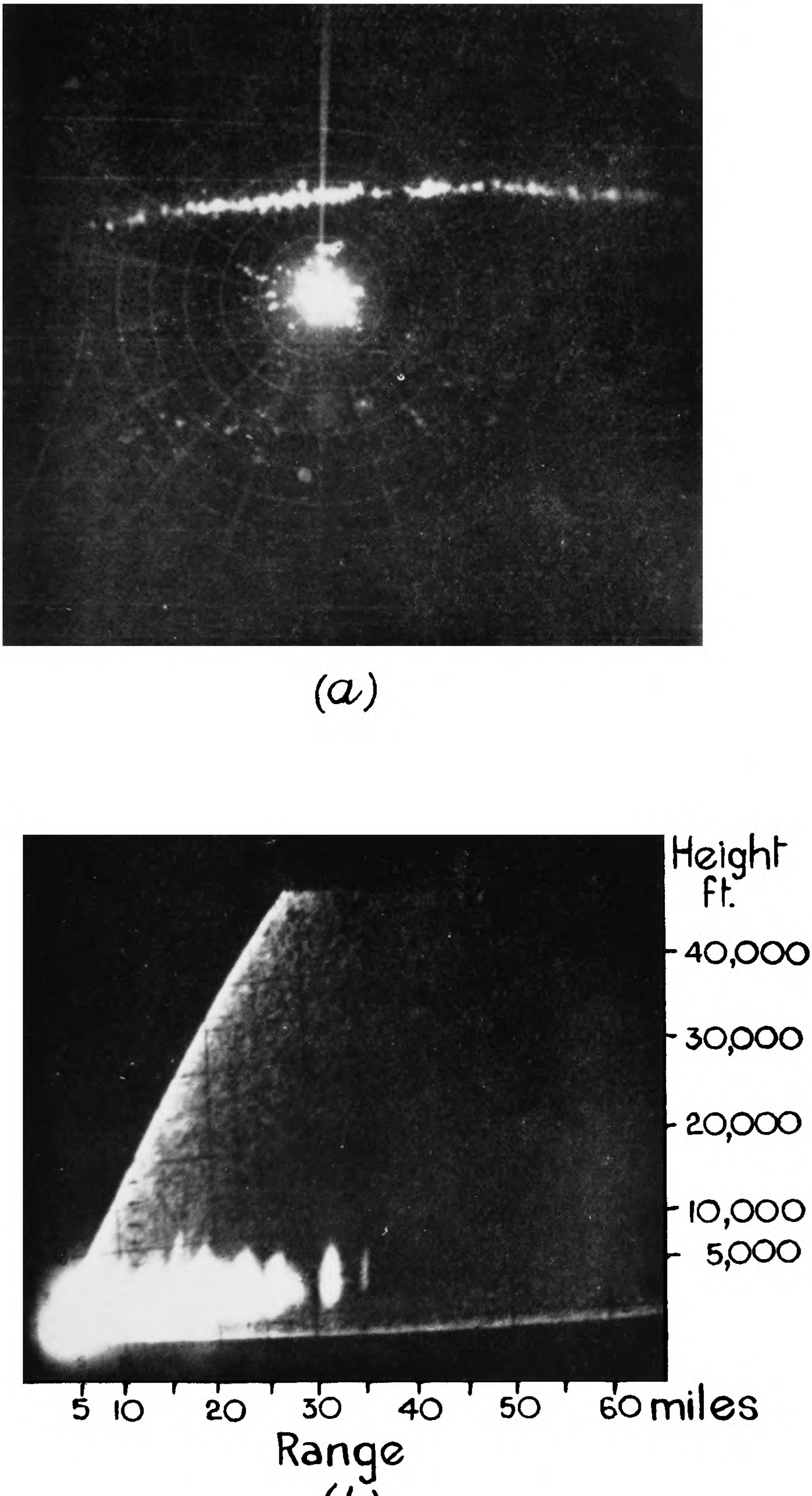
Since visibility as defined above is a subjective quantity, it cannot be measured directly by instrumental means. Even the eye cannot measure it directly at night. In order to find out what properties of the atmosphere can be used as an indirect means of determining visibility it is necessary to study the theory of visibility.

Theory of daylight visibility.—The theory put forward by Koschmieder[1] in 1924, and independently by Götz, has been checked experimentally from time to time and is now accepted as the best.

Koschmieder showed that the apparent brightness H_o of a black object viewed at a distance l against the horizon sky of brightness H_h is given by

$$H_o = H_h\,(1 - e^{-\sigma l}) \qquad \ldots (1)$$

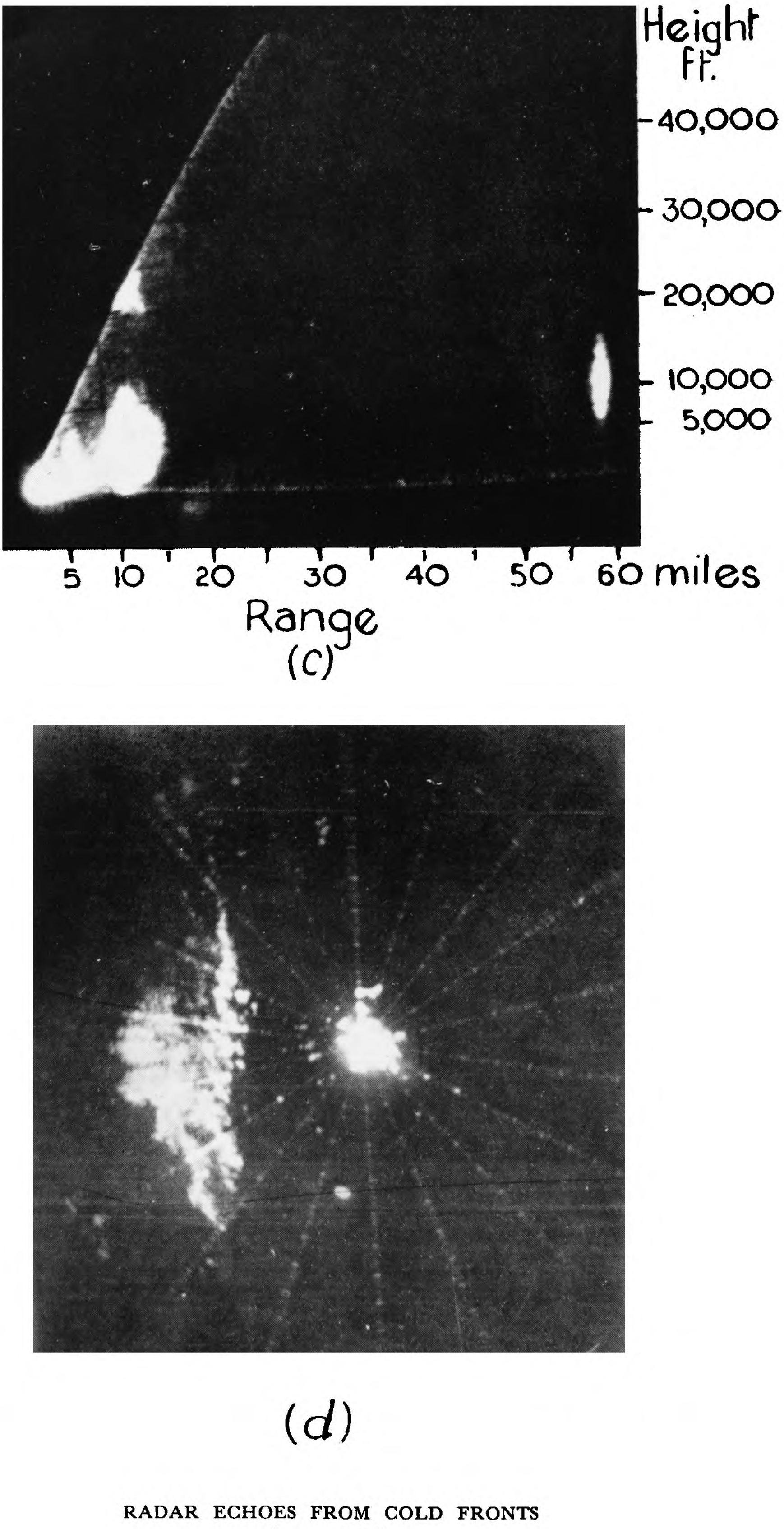
where σ is the extinction coefficient of the atmosphere. Both H_o and H_h are due to light scattered by the atmosphere, or the " air-light " as it is called.


Height
ft.
40,000
30,000
20,000
10,000
5,000
5
10
20
30
40
50
60
miles
Range

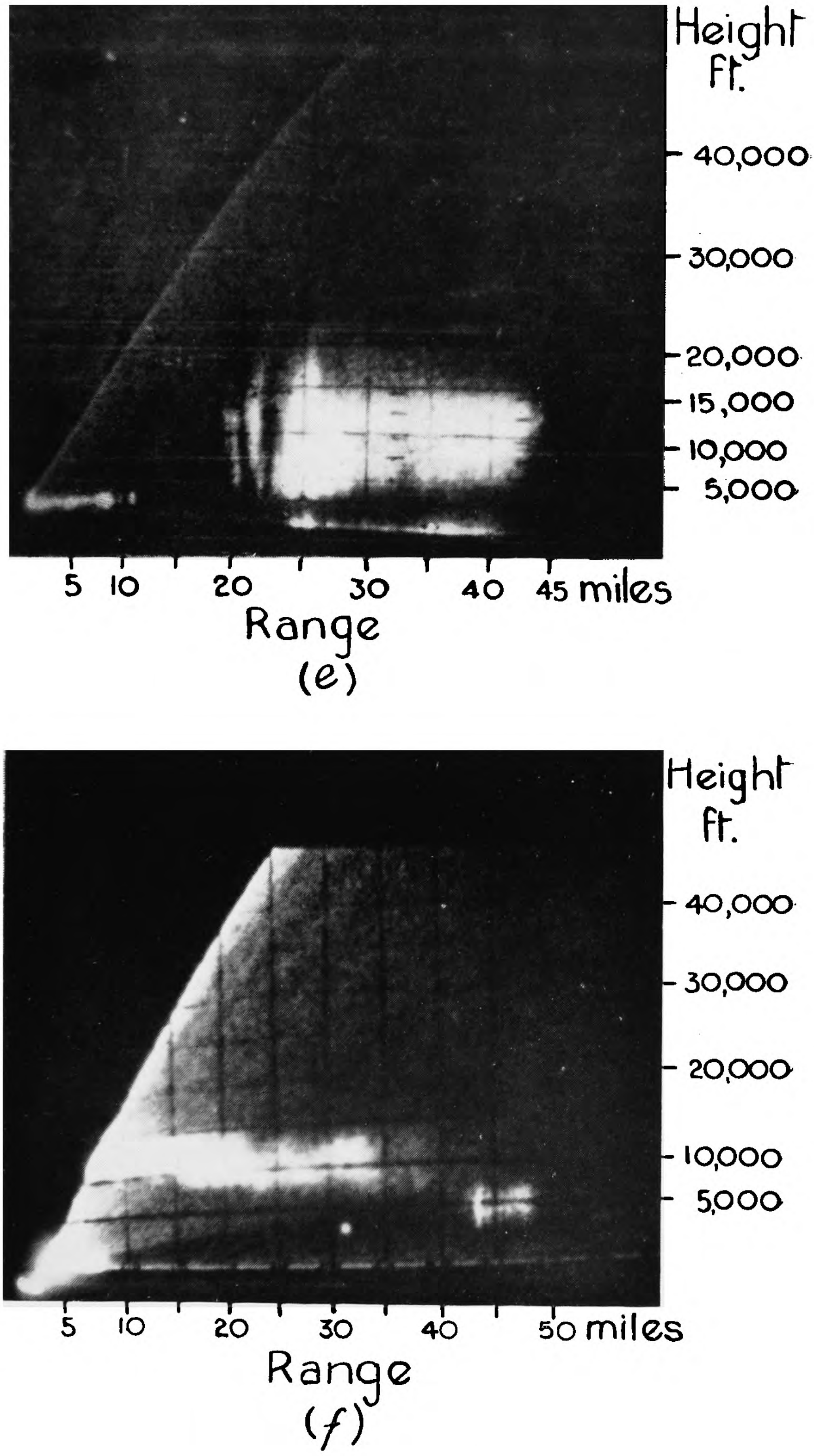
(a)

(b)

RADAR ECHOES FROM COLD FRONTS
(see p. 111)

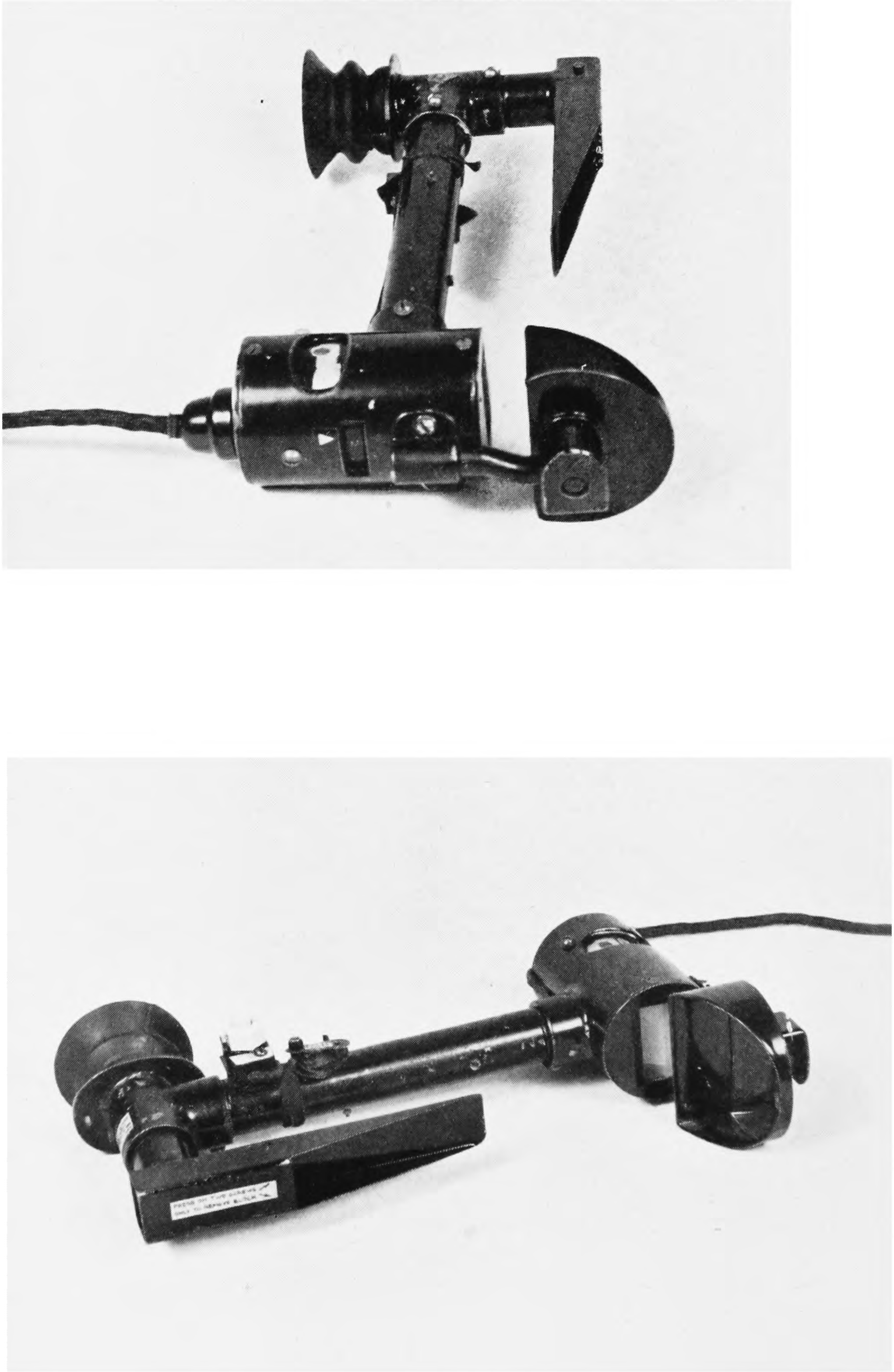

Height
ft.
40,000
30,000
20,000
10,000
5,000
5
10
20
30
40
50
60 miles
Range
(c)
(d)

RADAR ECHOES FROM COLD FRONTS
(see p. 111)



RADAR ECHOES FROM COLD FRONTS

(see p. 111)



BREWER-BEUTTELL VISIBILITY METER
(see p. 114)

In order to arrive at this result some simplifying assumptions are made, the most important being that the illumination and the coefficients of scattering and attenuation are constant along the line of sight from the eye to the object and to an infinite distance beyond.

For the contrast of the object against its sky background we have, from equation (1)

$$K = \frac{(H_h - H_o)}{H_h} = e^{-\sigma l}$$

If the object is only just visible, K becomes ϵ, the threshold of contrast, and l becomes V, the visibility, and we have

$$\epsilon = e^{-\sigma V}$$

or

$$V = \frac{1}{\sigma} \log_e \frac{1}{\epsilon} \qquad \ldots (2)$$

If ϵ is given the usual daylight value of 0·02 this becomes

$$V = \frac{3{\cdot}91}{\sigma} \qquad \ldots (3)$$

The scattering coefficient and the absorption coefficient do not appear in these expressions except as part of the extinction coefficient, which is their sum. Equations (1), (2) and (3) are therefore valid whatever the relative proportions of scatter and absorption, *i.e.* however much the atmosphere is polluted by absorbing matter such as smoke particles.

Daylight visual observations.—Extension of the theory shows that, if the object is not black, visibility is less, seriously so in fact for any but the darkest objects when illuminated by low sun. Experiment confirms this and shows that visibility varies also with the angular size of the object, if outside the range ½ to 5°, and from one observer to another (*i.e.* in equation (2) ϵ is not constant).

In order that visibility should be free from these variations and should represent only a state of the atmosphere, Löhle suggested the introduction of the concept " air-light range " which is the visibility computed for a black object and a contrast threshold of 0·02, *i.e.* V obtained from equation (3). Wright called this " standard visibility " and this term is generally used in Europe, although the necessary corrections to visual observations are not yet being made anywhere.

Visibility meters.—Turning now to the measurement of visibility instrumentally it is seen from equation (3) that the requirement is to measure σ. Instruments for doing this are divided into three main classes:—

I. Those measuring the air-light and using equation (1).

II. Those measuring σ directly from the attenuation of light from artificial sources.

III. Those measuring the scattering coefficient, which is equal to σ if absorption is negligible, *e.g.* at sea.

Visibility meters of class I.—Löhle's meter has two telescopes arranged to form images of the object and the adjacent sky, respectively, on the two parts of a Lummer-Brodhun photometric prism. The setting of an iris diaphragm in the sky telescope required to obtain a match gives H_o/H_h.

In Shallenberger and Little's meter[2], a thin prism is moved across an opening in a diaphragm over the object lens of a telescope until enough light from the sky is added to the normal images of object and sky to make the object only just visible. The prism setting gives H_o/H_h by means of an expression which unfortunately contains ϵ.

Waldram's " disappearance-range gauge " is almost identical, although developed independently.

These three daylight instruments are used for extrapolating for visibilities up to several times greater than the distance of the object.

Visibility meters of class II.—Middleton's " artificial-star " night-visibility meter[3] is arranged to produce an image of a built-in point source on the axis of a tube through which a distant light is viewed. A neutral wedge is used to reduce the apparent intensity of the distant light until a match is obtained. Matching of point sources is, however, difficult owing to the very rapid increase in sensitivity of the retina with distance from the central part or fovea.

The Gold night-visibility meter[4] is similar but has no comparison source. The wedge is used to reduce the apparent brightness of the distant light to the limit of perceptibility, *i.e.* to the visual threshold (of brightness). Conditions of observation are controlled so that the visual threshold is approximately constant for any one observer.

The Meteorological Office photo-electric meter uses a car headlamp to project a beam of light, and the attenuation of this is measured by means of two photo-cells, one close to the lamp and one 300 yd. away, which are connected in turn to a galvanometer. Very accurate alignment of lamp and photo-cell must be maintained. Calibration readings can be taken in weak daylight.

The American " transmissometer " is similar, but will work in full daylight and is arranged for distant recording.

Bergmann's meter[3] is also of the projector type but uses an interrupted light source so that steady currents due to daylight can be filtered out in the photo-cell circuits. It is a null method, the two photo-cells being connected in opposition. The beam is returned along its path by a corner reflector so that the two photo-cells are adjacent. This shortens the wiring but causes errors in fog due to the reinforcement of the return beam by back-scattered light from the outgoing beam. The instrument does not appear to have been developed, possibly because of its complication.

All the meters in this class are calibrated when visibility is good and known.

Visibility meters of class III.—In the Brewer-Beuttell meter[5] light from an opal window in front of a lamp is scattered through most angles along a 15-in. path into one half of the field of view of an eyepiece. The comparison half is provided by another opal window illuminated by the same lamp and its brightness is varied by means of an iris diaphragm to obtain a match. The instrument is hand-held and can be used only at night (see photograph facing p. 113).

The "Loofah hazemeter"[6] measures light scattered from a beam through an angle at which scattering is representative of total scattering. The scattered light is compared with the original source by means of a Lummer-Brodhun photometer. As the whole apparatus is contained in a light-tight box it can be used by day or night.

Accuracy.—The following rough estimates of errors show how the instruments described compare in this respect with direct visual observations, which are subject to errors of ±10 per cent. even in favourable circumstances.

With meters of the Shallenberger and Little type errors begin to exceed ±20 per cent. when visibility is 3 or 4 times the distance of the object used, assuming that a " greyness " correction is applied. Errors begin to exceed ±20 per cent. with Middleton's meter when the ratio of visibility to base-line is about 5, with the Gold meter when it is 2 or 3 and with the British and American photo-electric instruments when it is 10 or 20. The Bergmann meter should be much more accurate. In general, errors are less at lower visibility but with the scatter meters errors of ±20 per cent. are likely over the whole working range.

When visibility is not uniform all methods are subject to sampling errors which are more noticeable the shorter the base-line used and are at a maximum with the scatter meters.

Oblique visibility.—Oblique or slant visibility presents more difficult problems, both theoretical, because conditions are generally not uniform in the vertical, and practical, because one end of the base-line must be in the free atmosphere.

Two methods of observation are being tried out at Farnborough. One of these, due to Green of the Royal Aircraft Establishment, employs visual observations on pyrotechnic flares fired to 200 ft. The other, being developed by the Meteorological Office, uses as a source the light scattered from a small part of an inclined searchlight beam. The illumination from this source is measured at two different distances by means of photo-cells placed on the ground.

The Director, opening the discussion, referred to the important aviation aspect of visibility measurement. First, a scientific property of the atmosphere, such as extinction coefficient, had to be measured, and secondly this had to be converted into the form required, for example oblique visibility for the approach or horizontal visibility for the landing. A special feature of night operations was that very bright lights could be used so making landings possible in lower visibilities than by day.

Mr. Bibby asked if we needed to measure visibility to an accuracy greater than that of daylight visual observations. With regard to standard visibility he suggested that this be based not upon the unattainable black object but upon the average dark object of albedo 10 per cent. He thought we should reject the falsely high estimates of visibility obtained with the rising or setting sun directly behind the object, a situation in which, he pointed out, Koschmieder's theory is not valid. A difficulty with the photo-electric meter was that the regular calibrations required to ensure accuracy were sometimes interrupted for long periods owing to poor visibility. The searchlight type of oblique-visibility meter was being modified for daylight use by the provision of a modulated light source.

Mr. G. J. W. Oddie said he had hoped for advice on desirable accuracy from the synoptic and aviation people present. The objection to relating standard visibility to a grey object was that visibility could then depend on direction of observation even if the atmosphere were homogeneous. The photo-electric meter could be calibrated in poor visibility well enough to keep it in use for similar or lower visibilities.

Mr. Waldram (General Electric Company Research Laboratories, Wembley) said that there was sometimes confusion between meteorologist and user because the term " visibility " was used for the meteorological visual range, for the disappearance range of a particular object and for the conspicuousness of a well-seen object. Speaking of the photo-electric meters he doubted the possibility of obtaining the claimed accuracy when extrapolating to visibilities 10 or 20 times the base-line because errors in visibility were proportional to the degree of extrapolation. The scatter type of meter was useful in special circumstances such as in confined spaces or when the observer was moving. Movement incidentally improved sampling. The original Brewer-Beuttell meter had been made from odds and ends and therefore suffered from certain defects. It could undoubtedly be improved considerably. Meters of the Shallenberger and Little type might be very useful. Observations he had made with his own disappearance range gauge had shown a scatter of only ±7 per cent. with visibilities 3 or 4 times the distance of the object used. With regard to air-light measurements he had with him, for inspection afterwards, a Schuil telephotometer which could be used for this purpose.

Mr. G. J. W. Oddie confirmed Mr. Waldram's statement that errors with photo-electric meters were proportional to the ratio of visibility to base-line. Nevertheless, errors given for the transmissometer were equivalent to ±20 per cent. when this ratio was 16 while for Bergmann's meter Gurevich[9] claimed ±20 per cent. for a ratio of 1,600.

Mr. Parker (Ministry of Civil Aviation) who had done much of the flight testing of the high intensity approach and runway lights at London Airport stressed the importance of reports of oblique visibility. With shallow fogs he had often seen the approach lights three miles away.

Mr. Collins (Building Research Station), who had been concerned with the development of the "Loofah hazemeter" when at the Admiralty Research Laboratory, said that night visibility should be specified in some way which made it directly usable. Meters of the scatter type had their uses when purely local measurements were required. Referring to sampling errors he mentioned that for good visibilities elevated objects had to be used and the visibilities observed did not represent surface conditions. To illustrate these and other points he described some trials carried out by the Admiralty in Cardigan Bay.

Mr. G. J. W. Oddie pointed out that, given equivalent daylight visibility, extinction coefficient could be obtained from the relation

$$\sigma = \frac{3{\cdot}91}{V}$$

Mr. B. C. V. Oddie said that while errors with the photo-electric meter might generally be within the limits claimed they were apt to become very large suddenly and without warning. Did this also happen with the Gold meter and did the Gold meter give good results with users other than the opening speaker?

Mr. G. J. W. Oddie thought that these sudden large errors with the photo-electric meter were caused by loss of alignment. The Gold meter was not easy to use but it was much more reliable than mere estimation based on experience of the general appearance of miscellaneous lights. All members of the London Airport staff who used the Gold meter regularly, including recently recruited assistants, obtained equally good results with it.

Mr. Waldram said that the alignment of photo-electric meters could be checked by replacing the photo-cell by an eyepiece. Habitual users of photo-electric devices found it necessary to check their operation regularly. The extinction principle used in the Gold meter was not popular with photometricians. The state of dark adaptation of the eye was changing continuously and it was also difficult to keep the image on the fovea. Power supply variations caused the candle power of the lights used to drop to half in extreme cases.

Mr. G. J. W. Oddie said that Mr. Waldram's suggested method of checking alignment could presumably not be applied to the projector. Referring to the Gold meter he showed a slide which indicated that for foveal vision dark adaptation was complete within two minutes and that the visual threshold for parafoveal vision, which for the first two minutes was about the same as that for foveal vision, continued to decrease for more than half an hour. Variations in the candle power of the light used did not have as great a percentage effect on the computed visibility as long as visibility was poor. (*Communicated later*: a drop in intensity by 50 per cent. would cause the computed visibility to drop from 1,000 yd. to 850 yd., if a light at 1,000 yd. were being used.) He thought the main reasons for difficulty in using the Gold meter were that between extinction and reappearance of the light the observer's gaze tended to wander and his focus to relax. A nearer or brighter light in the field of view helped in both respects, and did not affect the visual threshold.

Mr. Band thought that the sudden changes in the photo-electric meter were caused not by alignment troubles but by variations in the photo-cells or by mains fluctuations too big for the constant voltage transformer to compensate. At Ringway they had found the Gold meter to work surprisingly well.

Mr. J. L. Galloway said that Siedentopf had extended Koschmieder's theory and had found that the formulae should hold even when there is a linear change of extinction coefficient with distance. He found experimentally that cloud shadows caused errors of only about ±10 per cent. Air-to-ground visibility was found to be a minimum towards the sun, instead of away from the sun as with horizontal visibility of a grey object in uniform conditions. Mr. Galloway thought that at some stations it was difficult to pick out the visibility lights from others when using the Gold meter. He pointed out that nearby buildings might seriously affect the indications of the photo-electric meter.

Mr. G. J. W. Oddie mentioned some recent experiments[7] carried out in the United States which confirmed Siedentopf's conclusion that lighting variations usually had little effect on visibility. If visibility lights were not conspicuous enough their candle power should be increased so that when the Gold meter was used other lights would disappear first.

Mr. Lane (Admiralty Research Laboratory) outlined an investigation which the Admiralty was about to start into the effect of size, shape and greyness of objects on their visual range.

Mr. Gold emphasised that daylight visibility was the best single form for stating both day and night visibilities as for night use conversion to visual range of lights was simple. He also stressed the importance of keeping visibility meters clean, and suggested that dirt might be responsible for the changes in photo-electric meters. For most practical purposes he thought that meters using a long base-line were superior to those which, like the scatter types, gave purely local visibility.

The Director, in closing the discussion, thanked the visitors who had contributed so much to the value of the discussion. Aviation, he said, presented special problems and it was not satisfactory to express visibility in the same way for all purposes. The aim must be for each meteorological office to be able to convert equivalent daylight visibility into the form required locally. With regard to slant visibility our first task was to investigate the variation of horizontal visibility with height.

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METEOROLOGICAL RESEARCH COMMITTEE

The eighth meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held on February 2, 1950.

The Chairman's report to the Committee was considered and the Sub-Committee also drew up recommendations for revision of that part of the Research Programme dealing with synoptic and dynamical matters.

A paper by Mr. J. M. Craddock*, dealing with the warming of cold air masses over the sea to the north-west of the British Isles, was discussed.

**Met. Res. Pap., London*, No. 526, 1949.

OFFICIAL PUBLICATION

The following publication has recently been issued:—

PROFESSIONAL NOTES

No. 98—Rainfall in east Scotland in relation to the synoptic situation. By R. F. M. Hay, M.A.

Rainfall in east Scotland was related with the synoptic situation, using Aberdeen hourly data and *Daily Weather Reports* for 1926–30. Depressions yielding falls of > 25 mm. at Aberdeen moved from between west-south-west and south-east on tracks converging to a region 60–125 miles south of Aberdeen. Less than 10 per cent. of these falls were accompanied by thunder. Simplified " tracks " were devised and average rainfalls estimated for depressions moving on them. The largest number of systems yielding falls > 3 mm. moved on tracks ("A" and " B ") from the Bay of Biscay north-north-east to a position off east Scotland and from Galway east-north-east through north England. Maximum average seasonal yields of rain from single depressions on most tracks occur in autumn (track B, 13 mm.) but for track C (east moving south of Aberdeen) the seasonal distribution is different, 11 mm. in summer and 4 mm. in winter. The chance of rainfall exceeding 10 mm. from a single system only reaches 40 per cent. with tracks A and B.

Warm occlusions moving north-eastwards mainly in autumn and winter produce the larger rainfalls at Aberdeen. Cold fronts yield little rain unless accompanied by considerable troughs. Results found were of some assistance in forecasting amounts of falls in Edinburgh in summer except in thundery situations, and were also generally applicable to other areas of east Britain.

The general results agree with theoretical considerations by several workers on rainfall and air movement near centres of depressions. Vertical moisture distribution also influences rainfall in these situations; most cases with Duxford tephigrams available showed " latent instability " with high humidities below 5,000 ft., above 5,000 ft. the tropical air was stable but usually very moist.

ROYAL METEOROLOGICAL SOCIETY AND INSTITUTE OF PHYSICS

A joint meeting was held in the Royal Institution on November 23, 1949, the subject for discussion being " The physics of atmospheric pollution ". It was opened by Dr. A. R. Meetham, who was until recently in charge of atmospheric pollution investigations at the Fuel Research Station, Greenwich.

He began by describing the methods of measuring atmospheric pollution, and gave a survey of the results obtained. The impurities formed by the burning of coal (ash, carbonaceous matter and sulphur dioxide) are naturally most abundant in industrial areas, while chlorides are found mostly near the coasts, indicating an origin in sea spray.

Approximate figures were given for the total deposition of the various impurities on Great Britain, the total being several million tons per year. These figures were compared with the estimated total output of impurities by coal burning, and considerable discrepancies between the two sets of figures were found.

Dr. Meetham proceeded to examine the causes of these. Ash appears to be over-estimated by the deposit gauges, which may be explained by the " ash " including a quantity of dust blown up from the ground. The quantity of ash emitted by chimneys is also subject to a good deal of uncertainty.

On the other hand, carbonaceous matter (soot and smoke) and sulphur dioxide are deposited in the gauges in much smaller amounts than are emitted by chimneys. This can be explained partly by the amount blown away to sea, but rough calculations showed that this could not account for all the discrepancy. The remainder is probably due to the fact that natural surfaces such as grassland present a much greater surface to the air than their nominal area, and so collect a correspondingly bigger deposit of pollution.

The chief points emphasised in the subsequent discussion were the especially damaging effect of sulphur dioxide in the air, and the advantage (to the user as well as the community) of domestic grates designed to burn smokeless fuel. Mr. Gold pointed out that some of Dr. Meetham's figures implied a considerable influx of smoke from outside this country, *e.g.* from France. Dr. Penman suggested that if any steps were to be taken to measure this it would be useful at the same time to check the migration of aphides from France to England.

Mr. Bonacina recalled smoke-laden fogs in London in the nineties, and asked whether there were any measurements of the obvious improvement since then. Dr. Meetham said that pollution measurements only started in 1914, but they showed a marked reduction of pollution between that year and 1922.

ROYAL METEOROLOGICAL SOCIETY

The Annual General Meeting of the Society was held on January 25, 1950, with the President, Sir Robert Watson-Watt, F.R.S., in the chair.

The President presented the Annual Report of the Council and announced the awards of Buchan Prizes and of the H. R. Mill Medal recently founded for recognition of research into rainfall problems. The Buchan Prizes were awarded to Dr. R. C. Sutcliffe and Mr. C. H. B. Priestley for their recent contributions to dynamical meteorology, and the H. R. Mill Medal to Dr. H. R. Mill, former Director of the British Rainfall Organization.

The President then delivered his Presidential Address on the " Evolution of Meteorological Institutions in the United Kingdom ". He opened his address by briefly describing the work of those British societies and institutions which had commenced the development of meteorology in the nineteenth century and went on to enumerate those bodies now actively engaged in the study and practice of the science. The work of learned societies, universities, private enterprise and the Meteorological Office received recognition. The President said his main object was not to describe the history of progress in meteorology in this country, which would be fully dealt with in the forthcoming Centenary celebrations, but rather to put forward what he conceived to be the primary objects of a Society composed of those who, as amateurs in the best sense, took a delight in the science in relation to the professional meteorological institutions. These objects were, he considered, the stimulation of the flow of trained physicists into meteorological work and encouragement of and assistance to them in their professional work. These objects would be fulfilled by vigorous development of the Society's facilities for the discussion and publication of meteorological research, and especially by facilitating discussions with those for whom, from directors of aviation companies to agriculturists, meteorological information was essential for efficient work. He drew especial attention to the need for further research into the application of meteorology to biological problems of all kinds. Finally, he analysed parts of the Annual Report of the Director of the Meteorological Office for the year 1948–49, and appraised the work of the Office in both research and the provision of meteorological information with special mention of its needs in staff and money.

LETTERS TO THE EDITOR

Extremes of humidity

The following extremes of humidity may be of interest. They were recorded by a hair hygrograph in a Stevenson screen during July 1949 at Swimbridge, north Devon, 450 ft. above M.S.L.

Date	Time	Dry bulb	Relative humidity	Vapour pressure
	G.M.T.	°F.	%	mb.
July 11	1600	84·5	14	6·0
July 12	1600	88·8	16	7·6
July 26	1300	73·8	68	19·5
July 27	0600	64·8	93	19·9

The low humidity on July 11 and 12 caused fir-cones of a maritime pine to explode with a noise similar to that made when a good-sized stick is thrown into a tree. These two readings are the lowest ever recorded by me.

However, the high readings were exceeded on July 31, 1938, when I recorded a vapour pressure of 22·9 mb. at 1800 at South Petherton, Somerset.

J. M. BRIERLEY

The Old Cyder House, Bydown, Swimbridge, N. Devon, August 1, 1949

Long periods with sunshine every day at Newquay

At Newquay, Cornwall, during the past 56 years, periods of 66 consecutive days or more with measurable sunshine were recorded in six years, namely:—

	days
1911, July 1 to September 11	73
1915, June 28 to September 14	79
1919, May 2 to July 20	80
1924, March 29 to June 2	66
1948, April 1 to June 5	66
1949, June 12 to September 17	98

Only two of the years mentioned above, namely 1911 and 1949, can safely be classified as good summers, and the following are the longest periods with measurable sunshine on consecutive days during some of the previous good summers:—

		days
1921	March 29 to May 10	43
	June 5 to July 22	48
1933	June 3 to July 12	40
	August 18 to October 17	61
1934	May 22 to June 20	30
	June 24 to July 31	38
	August 13 to September 18	37
1940	May 6 to June 21	47
	July 17 to September 13	59
1941	August 16 to September 26	42
1947	April 7 to May 16	40
	June 18 to July 19	32
	July 29 to September 13	47

F. J. HARRIS

10 Trelawny Road, Newquay, Cornwall, November 16, 1949

NOTES AND NEWS

Aircraft struck by lightning

On three occasions during the month of May 1949, Hastings aircraft from Dishforth were struck by lightning in circumstances that seem worthy of remark. Although weather conditions on all three occasions were unstable and local thunderstorms had been or were reported subsequently, at the times when the aircraft were struck no storms were observed in their vicinity, and radio atmospherics were not sufficiently excessive to suggest to the aircrew that there was a potential danger. Mr. T. H. F. Gifford, meteorological officer at Dishforth, has obtained the following information from the aircrews.

On May 15, an aircraft homeward bound from Malta was over northern France at 1100 G.M.T. flying at 6,500 ft. There were large broken cumulus clouds with bases at 4,000 ft. and tops extending to 14,000 ft. but no precipitation was observed. Turbulence was assessed as moderate, and radio atmospherics were not sufficient to suggest that the trailing aerial should be wound in. There was a loud report, a blue flash appeared to travel the length of the aircraft, and the trailing aerial was burnt off inside the aircraft at the winch. No other damage was sustained and the compasses were not affected. The synoptic situation at 0900 G.M.T. on that day showed a slow-moving thundery depression in the Toulouse area with thundery rain and local thunderstorms widespread over southern France and the Massif. Altocumulus castellatus was reported as far north as latitude 48°N. and scattered showers and large cumulus, base 3,000 ft., were reported over northern France. The situation was such as to suggest that a real risk of thunderstorms did not extend to northern France at that time of the day.

On the following day, May 16, another aircraft, also homeward bound from Malta, was just south of the central Massif in France, flying at 14,500 ft. At 1000 G.M.T. a flash of lightning carried away the trailing aerial, and the starboard outer motor stopped temporarily. There was no precipitation observed at the time but there were large cumulus clouds, base and tops unspecified, with patches of layer cloud. The general weather situation was similar to that of the previous day. The thundery depression had moved into the Gulf of Lions and cloud over the Massif was reported as large cumulus, with local thunder over the northern fringe at 1200 G.M.T. Presumably the aircraft was caught in the developing thundery conditions.

The third incident occurred in England over the Pennines, when an aircraft flying on a course from Dishforth to Shawbury was in cloud at 6,000 ft. at 1530 G.M.T. The aircraft had entered the cloud only very shortly before the lightning strike occurred, and while there were frequent hail showers radio atmospherics were not unduly pronounced. The flash appeared to originate from ahead of and above the cockpit and no damage appeared to have been sustained. Subsequent ground inspection showed that a hole had been punctured in the leading edge of the starboard main plane near the outer motor, a bolt of one of the inspection panels had been sheared and the panel partly ripped off. Another aircraft flying the same course 3 minutes in the rear flew through hail showers but radio atmospherics were not sufficient to occasion comment. At 1500 G.M.T. on that day the Pennines were in a north-westerly polar maritime air stream ahead of a developing ridge over Ireland. Cloud forms were of the convective type and scattered showers were reported at ground level. The 1500 G.M.T. Liverpool ascent was already showing signs of subsidence above 700 mb. with a freezing level at 6,000 ft. The forced ascent of air over the Pennines was presumably adding to its instability in the lower layers.

The conclusion to be drawn from these three incidents appears to be that, although convection conditions may not have developed to the stage where thunderstorms are observed, an aircraft can concentrate the atmospheric electric field in its immediate vicinity to a degree sufficient to cause the breakdown electric force of 10,000 v./cm. to be exceeded, thereby initiating a discharge.

METEOROLOGICAL OFFICE
38 GROUP, R.A.F.

REVIEW

Regression of climatic elements on latitude longitude and elevation in India. By P. Jagannathan. *Sci. Notes met. Dep. India, Delhi,* **10**, 1948, No. 121. Part I—Mean temperature, pp. 83–105. No. 122. Part II—Diurnal range of temperature, pp. 107–118. Size: 10 in. × 7 in. *Illus.* Part I—*Rs.* 2/2/- or 3*s.* 6*d.* and Part II—*Rs.* 1/2/- or 1*s.* 9*d.*

Jagannathan, in the first of a series of papers on the regression of climatic elements, has achieved for India what Hopkins* did for the Canadian prairies, namely, the computation of partial regressions of average temperatures on latitude, longitude and altitude for a wide selection of meteorological stations. Jagannathan bases his regressions for India as a whole upon 167 stations.

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*HOPKINS, J. W.; Agricultural meteorology: correlation of air temperatures in central and, southern Alberta and Saskatchewan with latitude, longitude and altitude. *Canad. J. Res. Ottawa,* C.**16** 1938, p. 16.

He also divides these into roughly equal groups characterising four main climatic regions. For each of these four regions and for India as a whole, partial regression coefficients for the twelve calendar months and the year are listed with their standard errors; and the corresponding multiple correlation coefficients show that, for the most part, the labour has been worth while. The reviewer was disappointed, however, to find that none of the correlation coefficients o temperature separately with latitude, longitude and altitude were given. Without such coefficients it is difficult to get any clear idea as to wha proportion of the average temperature variation is due to these factors. The addition also of mean values of all four variates would have been extremely useful, enabling other investigators to compute rapidly estimates of average temperature at places in India for which long-period normals are not available

The regression coefficient of temperature on altitude of station is seen to fluctuate about a mean value roughly equivalent to the average lapse rate in the free air (3°F./1,000 ft.). On recalculating for different altitude ranges, however, Jagannathan finds that a definite relation between height and temperature exists only for high altitude stations—those in the height ranges exceeding 1,000 ft.

Part II is similar to Part I, with average temperature replaced by the average difference between monthly mean maximum and minimum temperatures, and it suffers from the same omissions. Here the fit of the regression equations is not nearly so good; the dependence of range of temperature on altitude is non-significant in three of the four regions and, in the opinion of the reviewer, the inclusion of this third independent variable is scarcely worth the extra labour of computation that it must have involved. Linearity of regression is assumed throughout.

The author is to be congratulated on the achievement of such comprehensive regression analyses as those described in the two papers under review. His comments on the results are interesting and can be easily understood by the non-statistician.

N. CARRUTHERS

METEOROLOGICAL OFFICE NEWS

Air meteorological observers.—Since 1946 the Royal Air Force have provided observers for meteorological reconnaissance aircraft from pilots, navigators and air gunners: a return is now being made to the wartime practice of recruiting air meteorological observers from the staff of the Meteorological Office and scientific assistants who have begun, or are about to begin, their whole-time national service have been invited to volunteer. So the flying badge of air meteorological observer, well known by 1945 to the R.A.F. and the public, will soon be seen again, and valuable air experience will not be lost to the Meteorological Office when the observers complete their tour of duty.

Appointment as A.E.O.—Established scientific assistants will be interested to learn that the upper age limit for them has been raised from 25 to 30 in the 1950 competition for appointment as assistant experimental officers.

Married quarters.—Some additional quarters have been allocated to Meteorological Office staff at overseas stations. Three families will probably be accommodated at Changi (Singapore) by the end of the summer.

Central Forecasting Office.—In February the Central Forecasting Office celebrated the tenth anniversary of its inauguration at Dunstable. Sixteen members of the original staff of about one hundred are still serving at C.F.O., though one or two have seen duty elsewhere in the meantime.

In recent months the main forecast room in the original wartime hut accommodation of C.F.O. has been much improved by a new lighting installation, by removal of the partition which separated the surface and upper air work, and by the introduction of newly designed double-sided charting slopes. Now that the Forecast Research Division has its own new Napier Shaw Laboratory across the way (see Meteorological Office News, March 1950), more accommodation has become available for the other staffs at C.F.O., so that now the scientific and experimental officers and assistants each have their own rooms for study and non-routine work on normal duty periods.

Beaufort letter g.—It is odd that Beaufort, though an Admiral, made no provision for recording gales in his well-known letter notation: this has now been remedied. To make it easy for people who consult the *Daily Weather Report* to pick out occasions of gale, the meaning of g, hitherto allocated to " gloom ", has been altered from March 1, 1950. g and G now have the following meanings:—

g = gale (Beaufort force 8 or 9) and G = whole gale (force 10 or more),

the wind force in each case being maintained for a period of not less than ten minutes.

Thunderstorm location in Malta.—Using a radio teleprinter for communication, trials have recently been made of operating a thunderstorm-location (" sferic ") apparatus in Malta in conjunction with the British network. It has been found that the same lightning flashes can be identified in the United Kingdom and in Malta, and the long base-line allows storms in the Mediterranean area, central Europe and eastern Atlantic to be located with improved accuracy.

Experimental transmission of weather charts.—Using a facsimile apparatus and the ordinary telephone line transmissions of charts have been tried between C.F.O. and London Airport. A line chart 20 cm. × 13 cm. can be transmitted in about two minutes; for meteorological purposes an apparatus is needed which can reproduce a chart not less than 50 cm. × 40 cm. with clear detail.

A daylight illumination recorder, similar to the one which has been in use at Kew Observatory since 1947 has been installed on the roof of the Meteorological Office, Kingsway. It gives a continuous record of daylight illumination as it appears to the human eye, the eye being a selenium photocell, and the recorder a galvanometer in the forecast room. The purpose is to assess brightness in varying conditions of cloudiness, so that forecasts of cloud thickness and density can ultimately be given in terms of daylight brightness.

Ocean Weather Ships.—Following one of the decisions of last year's I.C.A.O. Conference in London on North Atlantic weather stations, by which the Netherlands provides one ship for occasional relief of the British ships on Station J (and also the French ships on Station K), the Netherlands' O.W.S. *Cumulus* will occupy Station J from April 15, in rotation with the British ships. The observations from *Cumulus* will be sent direct to C.F.O. as they are from the British ships. This co-operation between seamen and meteorologists of the two countries is now traditional, and *Cumulus* will be warmly welcomed when she arrives on station.

Magazines for Weather Ships.—Books or periodicals are very much appreciated by the ships' companies of O.W.S. Will readers of these columns who have any to spare, please send them to the Meteorological Office (M.O.1), Headstone Drive, Harrow, Middlesex, or to the Shore Captain, Ocean Weather Ship Base, Great Harbour, Greenock?

The Meteorological Association, now three years old, will hold its annual general meeting at the refectory of the Imperial College at 6.15 p.m. on April 21; tea will be served from 5 p.m. The Association has arranged to hold its third reunion dance at Crosby Hall, Cheyne Walk, Chelsea, at 7.30 p.m., on Saturday May 13. Tickets (3*s.* 6*d.* single, 6*s.* double) may be obtained from the Treasurer, Mr. W. P. Osmond, 238 Sheen Lane, East Sheen, S.W.16. Details will shortly be announced about this year's summer outing which will be a visit to C.F.O., Dunstable, on Saturday September 16.

The primary object of the Association is to further good fellowship among members, and to maintain wartime friendships. Anyone who is, or has been, a full-time practising meteorologist, either as a member of the Meteorological Office or of H.M. Forces, can become a member, and is invited to apply to the Treasurer (address above); the annual subscription is the modest sum of 2*s.* 6*d.*

Social activities.—As these notes go to press, arrangements have been completed for the annual evening social for members of the staff, their wives and friends in Victoria Hall, Bloomsbury Square. The party has become a firmly rooted function because it is one of the few opportunities our widely scattered staff have for meeting old friends and making new ones. Any profits go to enable Meteorological Office teams to take part in inter-departmental sports events.

Retirement.—Mr. S. F. Witcombe retired from duty with the Meteorological Office on March 31, after 34 years' service. Mr. Witcombe's first contact with meteorology was in the Meteorological Section, Royal Engineers, in 1916; in the course of his duties during the latter part of the 1914–18 war, he made many ascents in a manned balloon to make meteorological observations. Since 1918 Mr. Witcombe has spent most of his time on forecasting at M.O. Headquarters, Croydon, and Gloucester; more recently he has been examiner in meteorology for navigation certificates for pilots.

His many friends in the Meteorological Office and in Civil Aviation will always remember his outstanding work as a forecaster, his quiet imperturbable manner, and his readiness to help his younger and less experienced colleagues. The Meteorological Office suffers a loss with " Wit's " retirement, and wishes him well in the years ahead.

WEATHER OF FEBRUARY 1950

Mean pressure was between 1020 and 1025 mb. over an area that included part of Canada and most of the United States, and which extended across Bermuda and the Azores to Spain, Morocco and Algeria. It was below 1000 mb. from southward of Greenland across Iceland and northern Scotland to the west coast of Norway, and below 990 mb. over a small part of this region about 300 miles south-westward of Iceland. It was below normal over western Europe north of about latitude 43°N., but above normal around the Mediterranean and over most of Canada and the United States.

In the British Isles the weather was unsettled and wet, exceptionally so over England and Wales, where it was the wettest February since the record wet month of 1923, although February 1937 was almost as wet. Mean temperature exceeded the average in the south but was slightly below the average in the north.

The morning of the 1st was cold and some low minimum temperatures were registered; for example, 15°F. at Leeming and 11°F. at Eskdalemuir. Thereafter, a deep depression was centred south-east of Greenland, while troughs or secondary depressions passed over or near the British Isles causing frequent and heavy rainfall (2·43 in. at Treherbert, Glamorgan, and 2·35 in. at Ashburton, Devon, on the 1st and 2·29 in at Borrowdale, Cumberland, and 2·18 in. at Cricket St. Thomas, Somerset, on the 2nd). The main depression moved little but became less deep. On the 6th another deep depression in mid Atlantic moved to south-west Iceland and on the 7th a trough of low pressure crossed the British Isles giving further rain or showers. Subsequently, new disturbances developed over the Atlantic and associated troughs, crossing this country, caused more rain which was heavy locally at times; for example, in Wales on the 9th, when 2·65 in. was registered at Lake Vyrnwy. On the 11th a complex depression moved across Scotland and was followed on the 12th and 13th by another disturbance which crossed Ireland and England; rain occurred daily in most areas. From the 13th to 16th the Azores anticyclone moved east-north-east to the Alps, while another deep Atlantic depression moved north-east and troughs or small secondary depressions affected the weather of the British Isles; mild weather, with heavy local rain, prevailed. Rainfall amounted to 3·38 in. at Fort William, 3·00 in. at Ardgour, Argyllshire, and 2·08 in. at Loch More, Sutherland, on the 16th. The frequent heavy rains of the first sixteen days caused considerable flooding in some districts. Much of England came under the influence of the continental anticyclone from the 15th to 18th and experienced a mainly dry spell so that the flood subsided. This latter period was very mild and temperature reached 61°F. at Mildenhall and London Airport and 59°F. at Kew Observatory and some other stations in the southern half of the country on the 17th. Further rain occurred, however, on the 19th and 20th. Subsequently, high pressure was established over France, with a wedge extending over England and a short spell of mainly fair weather occurred, but still more rain fell on the 23rd when a trough crossed England and Wales.

On the 24th and 25th a depression off south-west Ireland moved south-east and then east over northern France and colder NE.—N. winds prevailed; substantial amounts of snow fell in some northern districts, and smaller falls in the south-east, which soon melted. A ridge of high pressure followed, which dominated eastern and Midland districts until the end of the month, with keen to hard frosts in many places.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales	63	12	+2·3	220	+3	103
Scotland	56	6	−1·2	127	+1	134
Northern Ireland..	60	18	−0·5	117	+3	98

RAINFALL OF FEBRUARY 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ..	3·30	198	*Glam.*	Cardiff, Penylan ..	6·97	237
Kent	Folkestone, Cherry Gdn.	3·99	197	*Pemb.*	St. Ann's Head ..	8·19	292
,,	Edenbridge, Falconhurst	5·92	268	*Card.*	Aberystwyth	5·07	204
Sussex	Compton, Compton Ho.	6·69	254	*Radnor*	Tyrmynydd	10·29	196
,,	Worthing, Beach Ho.Pk.	4·33	219	*Mont.*	Lake Vyrnwy	13·13	288
Hants	Ventnor, Roy. Nat. Hos.	5·03	240	*Mer.*	Blaenau Festiniog ..	13·30	163
,,	Bournemouth	5·34	224	*Carn.*	Llandudno	5·29	271
,,	Sherborne St. John ..	4·44	203	*Angl.*	Llanerchymedd ..	5·07	200
Herts.	Royston, Therfield Rec.	3·23	210	*I. Man.*	Douglas, Borough Cem.	4·68	147
Bucks.	Slough, Upton	3·85	227	*Wigtown*	Port William, Monreith	3·75	122
Oxford	Oxford, Radcliffe ..	4·09	250	*Dumf.*	Dumfries, Crichton R.I.	3·02	92
N'hant.	Wellingboro', Swanspool	3·70	230	,,	Eskdalemuir Obsy. ..	6·37	129
Essex	Shoeburyness	2·43	198	*Roxb.*	Kelso, Floors	3·07	181
Suffolk	Campsea Ashe, High Ho.	2·54	184	*Peebles*	Stobo Castle	4·49	163
,,	Lowestoft Sec. School ..	2·29	164	*Berwick*	Marchmont House ..	2·57	124
,,	Bury St. Ed., Westley H.	3·06	204	*E. Loth.*	North Berwick Res. ..	1·72	110
Norfolk	Sandringham Ho. Gdns.	3·98	241	*Midl'n.*	Edinburgh, Blackf'd. H.	2·68	161
Wilts.	Bishops Cannings ..	4·98	235	*Lanark*	Hamilton W. W., T'nhill	4·47	154
Dorset	Creech Grange.. ..	5·56	195	*Ayr*	Colmonell, Knockdolian	3·38	88
,,	Beaminster, East St. ..	7·06	234	,,	Glen Afton, Ayr San ..		
Devon	Teignmouth, Den Gdns.	6·40	241	*Bute*	Rothesay, Ardencraig	4·78	119
,,	Cullompton	6·13	220	*Argyll*	L. Sunart, Glenborrodale	6·38	106
,,	Ilfracombe			,,	Poltalloch	6·49	151
,,	Okehampton, Uplands	10·03	236	,,	Inveraray Castle ..	9·70	143
Cornwall	Bude, School House ..	4·93	197	,,	Islay, Eallabus ..	5·36	128
,,	Penzance, Morrab Gdns.	7·31	219	,,	Tiree	5·16	150
,,	St. Austell	8·51	222	*Kinross*	Loch Leven Sluice ..	3·09	109
,,	Scilly, Tresco Abbey ..	6·58	236	*Fife*	Leuchars Airfield ..	1·81	103
Glos.	Cirencester	6·55	290	*Perth*	Loch Dhu	9·43	127
Salop.	Church Stretton ..	5·50	235	,,	Crieff, Strathearn Hyd.	3·99	113
,,	Cheswardine Hall ..	5·07	285	,,	Pitlochry, Fincastle ..	5·35	182
Worcs.	Malvern, Free Library	4·66	259	*Angus*	Montrose, Sunnyside ..	2·21	120
Warwick	Birmingham, Edgbaston	5·28	312	*Aberd.*	Braemar	3·99	140
Leics.	Thornton Reservoir ..	4·22	253	,,	Dyce, Craibstone ..	3·40	148
Lincs.	Boston, Skirbeck ..	3·20	219	,,	Fyvie Castle	3·65	163
,,	Skegness, Marine Gdns.	3·41	223	*Moray*	Gordon Castle	2·38	124
Notts.	Mansfield, Carr Bank ..	4·58	237	*Nairn*	Nairn, Achareidh ..	1·82	112
Derby	Buxton, Terrace Slopes	7·14	190	*Inverness*	Loch Ness, Garthbeg ..		
Ches.	Bidston Observatory ..	3·99	239	,,	Glenquoich	12·13	117
Lancs.	Manchester, Whit. Park	4·03	210	,,	Fort William, Teviot ..	11·13	148
,,	Stonyhurst College ..	5·22	156	,,	Skye, Duntuilm ..	5·49	119
,,	Blackpool	4·21	188	*R. & C.*	Tain, Tarlogie House ..	2·35	103
Yorks.	Wakefield, Clarence Pk.	4·26	249	,,	Inverbroom, Glackour..	5·26	103
,,	Hull, Pearson Park ..	3·61	217	,,	Applecross Gardens ..	5·79	115
,,	Felixkirk, Mt. St. John	3·20	189	,,	Achnashellach	7·43	108
,,	York Museum	3·37	223	,,	Stornoway Airfield ..	3·87	91
,,	Scarborough	3·08	183	*Suth.*	Loch More, Achfary ..	7·17	109
,,	Middlesbrough.. ..	2·46	189	*Caith.*	Wick Airfield	1·90	84
,,	Baldersdale, Hury Res.	6·73	224	*Shetland*	Lerwick Observatory ..	5·09	161
Norl'd.	Newcastle, Leazes Pk. ..	3·58	234	*Ferm.*	Crom Castle	4·01	137
,,	Bellingham, High Green	4·41	174	*Armagh*	Armagh Observatory ..	2·78	125
,,	Lilburn Tower Gdns. ..	3·15	158	*Down*	Seaforde	4·27	140
Cumb.	Geltsdale	4·81	185	*Antrim*	Aldergrove Airfield ..	272	113
,,	Keswick, High Hill ..	6·77	137	,,	Ballymena, Harryville..	3·18	99
,,	Ravenglass, The Grove	4·77	155	*L'derry*	Garvagh, Moneydig ..	2·98	95
Mon.	Abergavenny, Larchfield	7·00	220	,,	Londonderry, Creggan	3·60	113
Glam.	Ystalyfera, Wern House	10·52	205	*Tyrone*	Omagh, Edenfel ..	3·47	116

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, OCTOBER 1949

STATIONS	PRESSURE		TEMPERATURES							REL-ATIVE HUM-IDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Per-centage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1016·0	+1·8	73	30	61·5	47·7	54·6	+3·6	51·6	87	6·0	5·24	+2·54	14	3·7	35
Gibraltar	1020·3	+3·1	82	54	75·4	63·7	69·5	+3·1	65·0	81	4·3	0·00	—	0	7·7	68
Malta	1018·5	+2·5	82	58	74·5	63·8	69·1	−1·8	65·9	74	4·6	7·32	—	14	7·0	62
St. Helena	1017·3	−0·5	70	53	63·3	54·1	58·7	0·0	55·0	98	7·9	2·24	+0·53	17	—	—
Lungi, Sierra Leone	1012·8	—	90	69	85·3	71·5	78·4	—	73·8	89	6·0	12·66	—	20	6·8	57
Lagos, Nigeria ..	1012·0	+1·0	89	67	86·4	70·0	78·2	−1·5	76·8	85	6·6	10·09	—	17	6·4	54
Kaduna, Nigeria ..	1010·4	—	93	59	88·5	65·6	77·1	−0·6	70·9	71	5·3	1·62	−1·13	6	8·0	67
Chileka. Nyasaland	1015·9	+0·3	95	59	89·6	67·1	78·3	+0·2	64·2	50	1·5	0·79	−0·27	2	8·6	69
Lusaka, Rhodesia ..	1011·0	+0·4	99	57	92·5	64·1	78·3	+2·0	60·2	36	0·9	0·01	−0·50	1	9·9	80
Salisbury, Rhodesia	1014·6	+0·3	90	72	83·6	58·2	70·9	+0·6	56·7	44	1·3	0·09	−1·06	2	9·8	78
Cape Town	1016·7	−0·7	93	43	71·5	54·0	62·7	+1·5	52·7	59	3·7	1·04	−0·61	8	—	—
Palmietfontein, S. Africa	1015·3	—	87	39	79·3	53·5	66·4	—	54·7	58	3·0	2·65	—	10	9·3	—
Mauritius	1018·7	+0·5	85	58	80·4	63·7	72·1	−0·6	63·7	62	4·4	0·61	−1·06	12	7·2	58
Calcutta, Alipore Obsy.	1008·4	−1·1	94	69	91·1	76·5	83·8	+4·5	78·8	76	3·6	3·60	−1·30	12	7·3	63
Bombay	1008·7	−1·1	95	71	88·7	76·9	82·8	+0·4	77·4	80	4·2	1·35	−0·32	7	7·6	65
Madras	1007·7	−1·2	97	74	91·3	76·9	84·1	+1·8	76·7	77	4·3	3·45	−7·70	12	7·5	64
Colombo, Ceylon ..	1010·2	+0·2	87	73	85·3	76·1	80·7	+0·2	71·1	59	5·3	13·04	−0·32	16	6·6	55
Singapore	1009·8	+0·1	90	73	87·5	76·4	81·9	+0·8	76·6	80	6·7	3·19	−4·88	14	7·1	59
Hongkong	1012·4	−1·3	91	68	81·7	72·7	77·2	+0·3	70·1	71	—	3·06	−1·88	6	6·0	52
Sydney, N.S.W. ..	1010·9	−3·9	89	44	76·0	59·9	67·9	+4·3	60·9	60	4·0	1·51	−1·34	9	8·2	63
Melbourne	1007·8	−7·0	80	37	66·7	49·1	57·9	+0·2	52·6	63	6·6	5·06	+2·43	24	3·9	30
Adelaide	1009·2	−6 8	87	43	68·5	51·6	60·1	−1·8	53·9	60	5·0	5·24	+3·50	17	5·6	43
Perth, W. Australia	1015·2	−1·6	83	43	68·5	50·6	59·5	−1·3	55·9	68	5·0	2·93	+0·71	18	7·4	58
Coolgardie	1014·5	−0·4	91	39	74·7	48·7	61·7	−2·0	52·7	55	3·3	1·02	+0·36	6	—	—
Brisbane	1014·9	−1·3	89	58	79·1	63·6	71·3	+1·5	65·3	71	4·8	11·41	+8·88	14	7·0	55
Hobart, Tasmania	1005·4	−4·9	69	37	59·4	45·3	52·3	−1·8	47·8	66	6·8	3·78	+1·52	23	3·4	26
Wellington, N.Z. ..	1015·1	+1·5	64	40	59·0	49·3	54·1	+1·1	52·2	82	6·5	2·78	−1·30	13	6·3	48
Suva, Fiji	1013·8	+0·6	83	65	79·7	70·6	75·1	−0·7	71·3	82	5·7	8·12	−0·17	21	6·4	51
Apia, Samoa ..	1011·2	+0·2	87	68	85·7	72·7	79·2	−0·3	75·2	83	5·3	9·68	+2·51	20	6·6	53
Kingston, Jamaica	1012·1	+0·6	93	67	88·7	73·6	81·1	+0·6	75·3	78	3·0	3·02	−4·44	8	8·1	69
Grenada, W. Indies																
Toronto	1020·5	+3·0	79	32	62·9	48·2	55·5	+6·9	48·8	86	6·8	1·82	−0·75	9	5·2	47
Winnipeg	1012·7	−2·2	71	7	49·5	33·0	41·3	+0·6	35·3	85	7·2	5·67	+4·30	13	4·0	37
St. John, N.B. ..	1020·9	+5·1	69	29	58·4	43·1	50·7	+5·4	45·2	86	5·4	2·60	−1·94	11	5·9	54
Victoria, B.C. ..	1020·4	+3·3	61	29	54·7	38·5	46·6	−3·7	42·3	91	5·6	2·61	+0·04	11	4·3	39

M.O. 533 AIR MINISTRY

METEOROLOGICAL OFFICE

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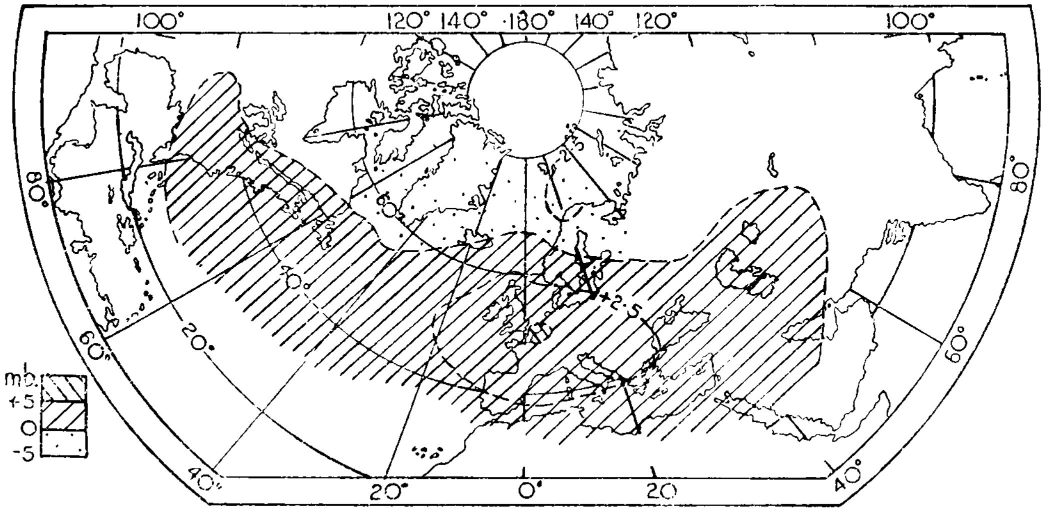
RECENT LONG PERIOD WITH PRESSURE ABOVE NORMAL OVER EUROPE AND THE NORTH ATLANTIC

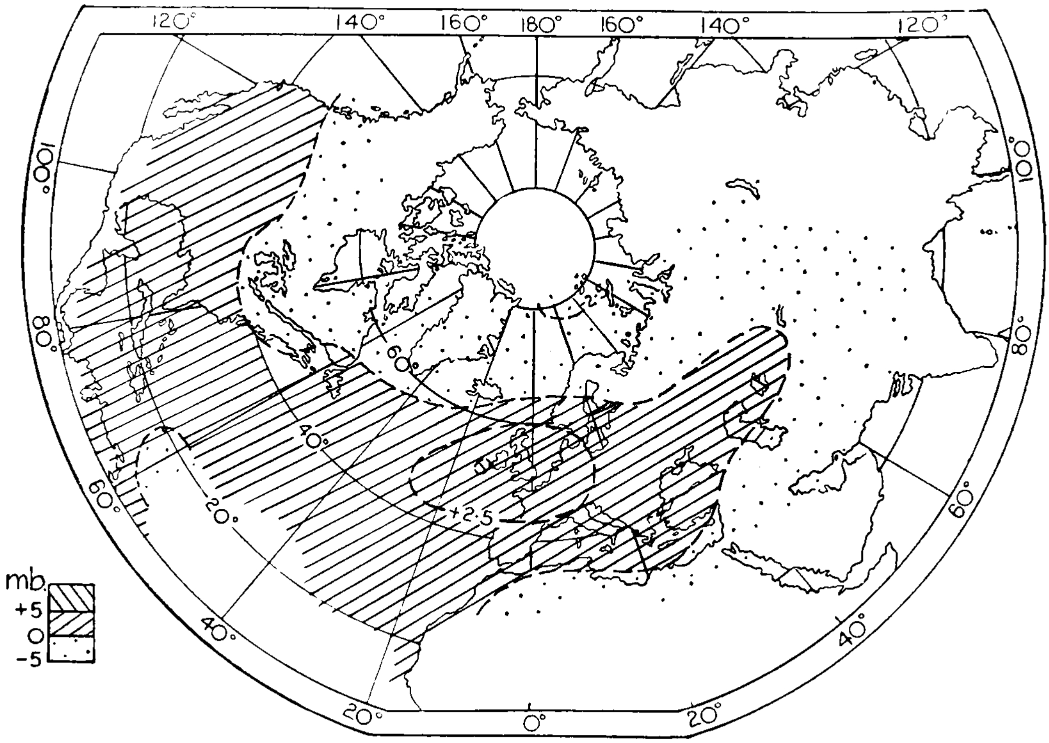
By E. V. NEWNHAM, B.Sc.

Fig. 1 shows isopleths of pressure for intervals of 2·5 mb. for the period October 1948–September 1949. They indicate an area with pressure above normal extending from the Mississippi to central Asia, with an excess of more than 2·5 mb. in an area centred over Belgium, and covering about 50 degrees of longitude and 20 degrees of latitude. Over part of south-east England, northern France, Belgium and Holland the excess was about 5 mb. Examination of the monthly maps of pressure anomaly for the period 1873–1941, prepared by Dr. C. E. P. Brooks, showed only one period (February–December 1921) with pressure anomaly roughly comparable in size and duration, but in 1921 there was no succession of months with closely similar anomaly such as the four months January–April 1949 (Figs. 2–4) ; moreover there is no such period in all the 69 years, instances of even two successive similar monthly



October 1948–September 1949

FIG. 1—PRESSURE ANOMALIES


120°
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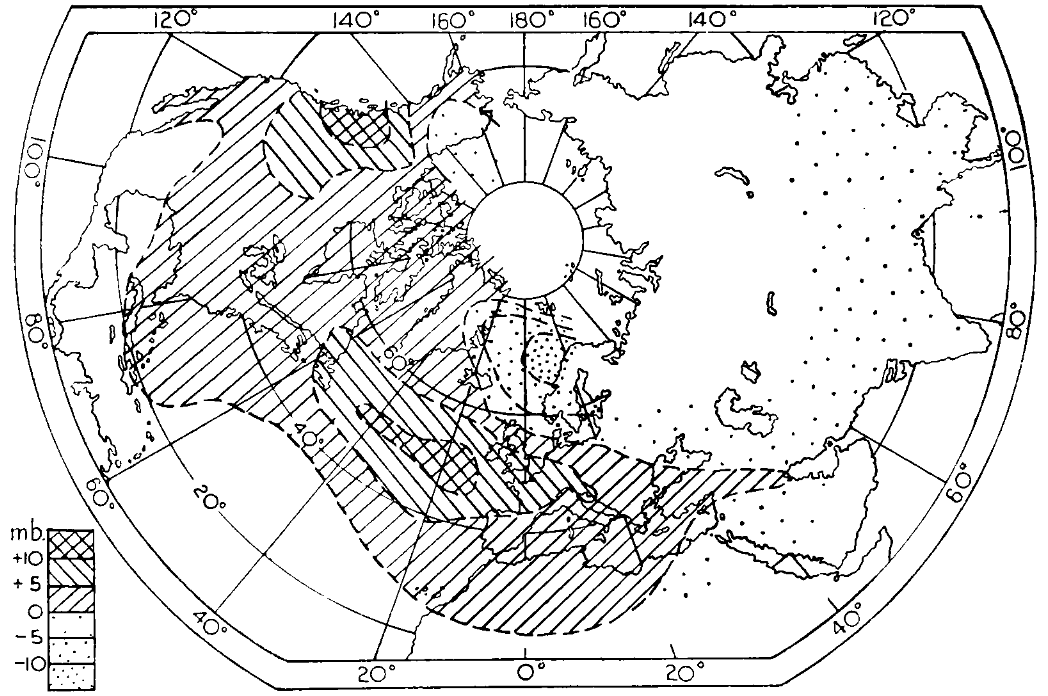
40°
20°
+2.5
mb.
+5
0
-5

February–December 1921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120°
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80°
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60°
60°
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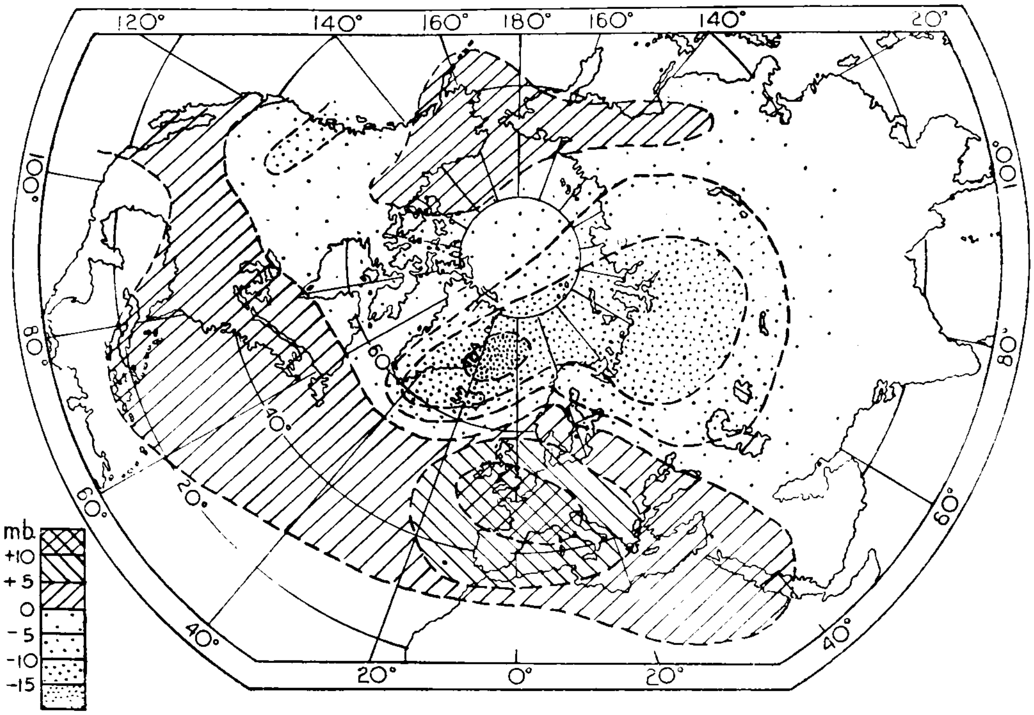
40°
20°
0°
20°
60°
40°
20°
mb.
+10
+5
0
-5
-10

January 1949

FIG. 2—PRESSURE ANOMALIES

maps being very uncommon. It appears, therefore, that there was in 1949 a general disturbance of the normal distribution of pressure over the northern hemisphere of unique persistence.

The following are the most noteworthy long periods with mean pressure above normal in addition to October 1948–September 1949:—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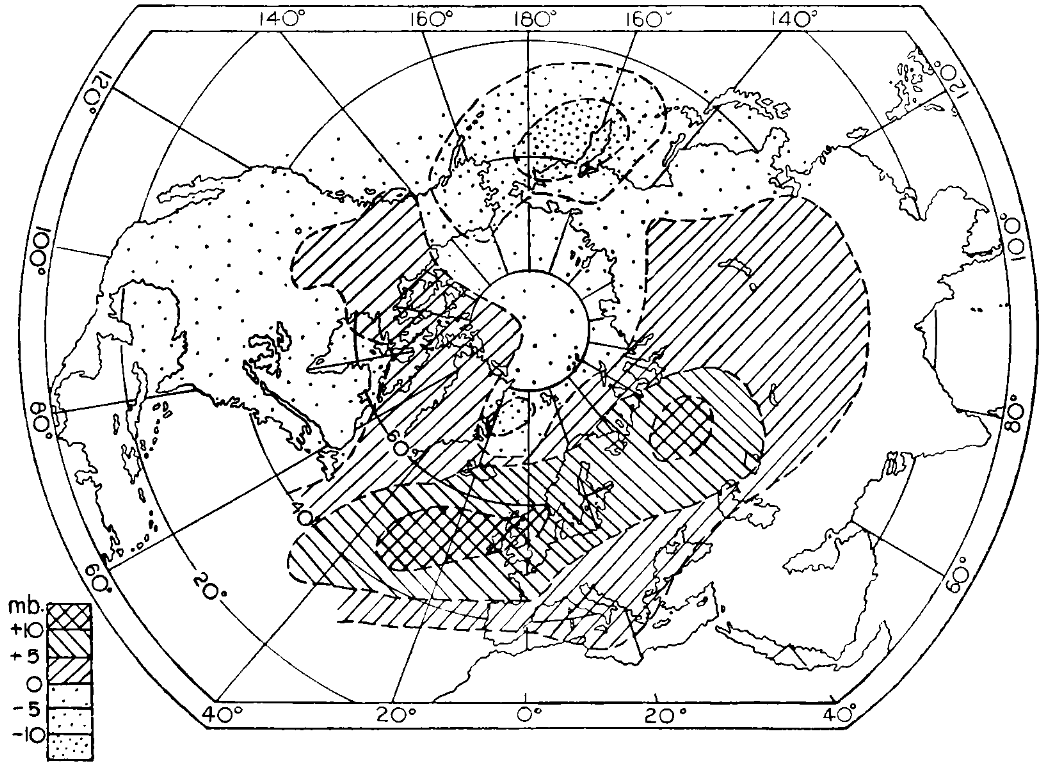
20°
0°
20°
mb.
+10
+5
0
-5
-10
-15

February 1949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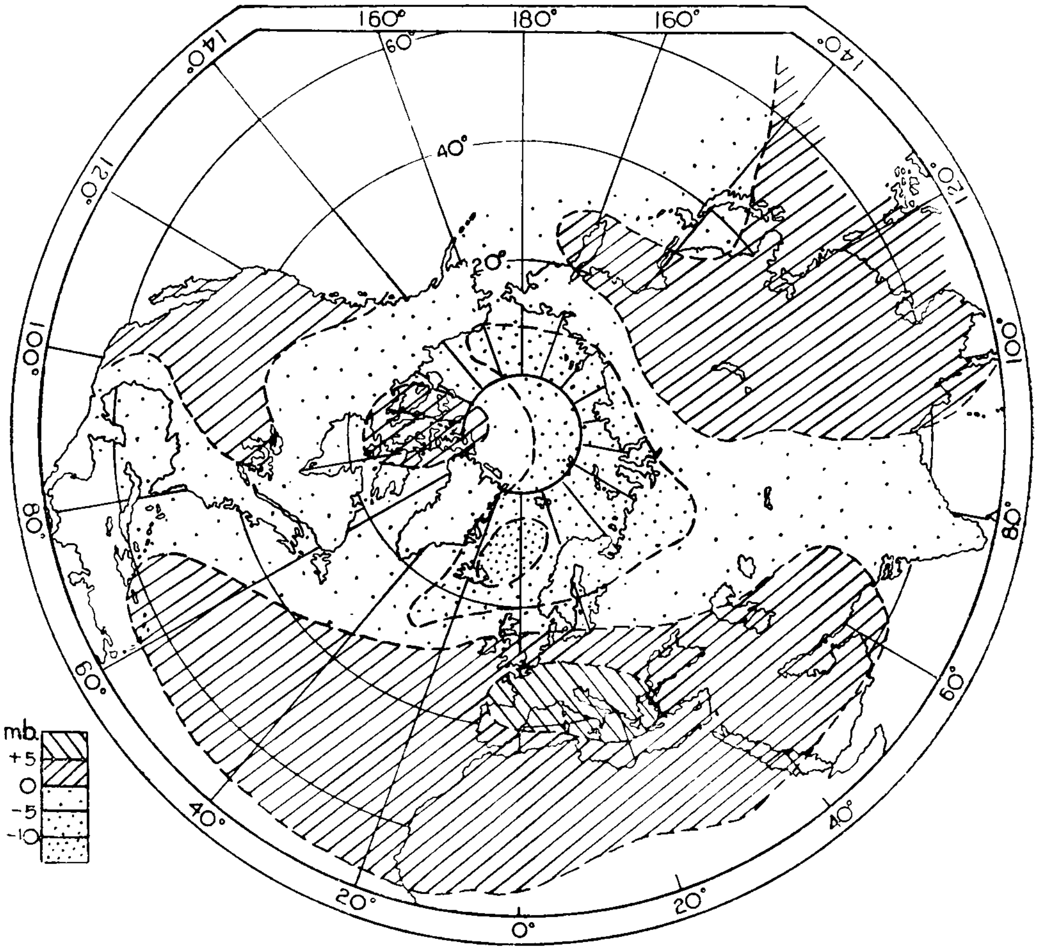
40°
20°
40°
20°
0°
20°
40°
mb.
+10
+5
0
-5
-10

March 1949

FIG. 3—PRESSURE ANOMALIES

(*a*) From October 1883 to January 1884 pressure was above normal over the North Atlantic south of about latitude 60°N., and over southern and central Europe, the excess being a little over 4 mb. over the Bay of Biscay. After a break of five months there was a second period, this time lasting five months (July–November 1884) with pressure 3 or 4 mb. above normal over Europe and at least the western parts of Russia.

(*b*) During the six months September 1904–February 1905 pressure was above normal over Persia, the Mediterranean, southern and central Europe, and over the North Atlantic to about longitude 30°W., the excess being nearly 4 mb. in northern France.

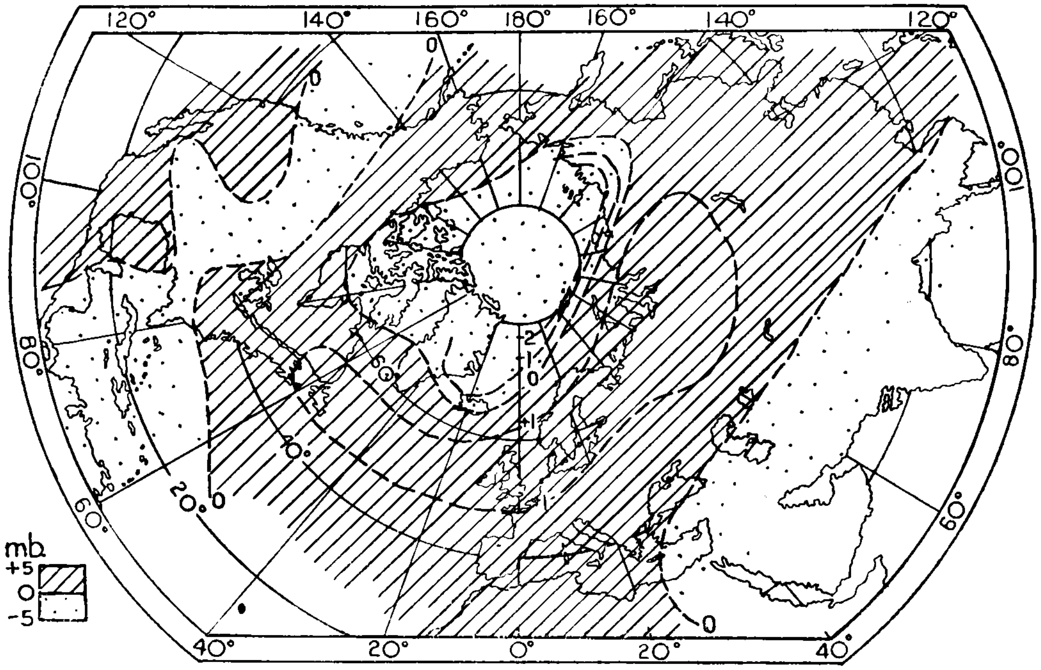


April 1949

FIG. 4—PRESSURE ANOMALIES

(*c*) From February to December 1921 pressure was above normal from central Asia westwards at least so far as the Pacific coast of the United States of America (see Fig. 2). The region with excess of more than 2·5 mb. was rather smaller than in 1948–49, and lay about 10 degrees further west, and the only region where the excess may have reached 5 mb. was a small one west or south-west of Valentia. As has already been mentioned this period is comparable in some ways to 1948–49.

(*d*) A rather different type of excess pressure is that of the much longer period (25 months) from November 1932 to November 1934. This is shown in Fig. 5, the isallobars being for intervals of 1 mb. The excess was smaller than for the shorter periods dealt with so far, but was nearly 2 mb. over a large area in northern Russia and the north-west of Siberia. It can be seen that the area with pressure above normal was very large, including the North Atlantic, Europe and a large part of Asia.



November 1932–November 1934
FIG. 5—PRESSURE ANOMALIES

(*e*) The last period which deserves mention is the nine months February–October 1939. Pressure was above normal from northern Asia across Europe and the North Atlantic to north-east Canada, and almost to the east coast of the United States. The excess was more than 2·5 mb. in Sweden, northern Norway and Finland, but was less than 1 mb. over most of the region.

DIURNAL VARIATION OF UPPER WIND AT FREETOWN

By W. H. HOGG, M.Sc.

Pilot-balloon records from Freetown (8°30′N., 13°14′W.) giving the wind direction and speed at 0600, 1100 and 1600 zone time for intervals of a thousand feet are available for the period July 1944–June 1946. Ascents have now ceased and the two years' observations have been summarised to give some indication of the diurnal variation of wind in the lowest few thousand feet.

The use of mean values from pilot-balloon data has been criticised, as the results are usually biased in favour of clear weather with little cloud and light wind. Their use in the present investigation can, however, be justified on two grounds; first, that the bias is less marked near the ground than at a height of several thousand feet, and secondly, that any bias will be in favour of days with marked land and sea breezes, which are the main causes of the diurnal variation.

The data were summarised by computing monthly vectors for 0600, 1100 and 1600. In the computation, only those heights were included which were reached by each ascent during the day; for example, if the 0600 ascent reached

4,000 ft., the 1100 reached 3,000 ft. and the 1600 reached 5,000 ft., only the observations up to 3,000 ft. were included for this day. The monthly vectors were then combined to give vectors for the following seasons: dry season (December–April), first squall season (May–June), monsoon season (July–September) and second squall season (October–November). Table I contains these vectors for heights up to 4,000 ft.; they are measured clockwise in degrees from north and in knots. The vectorial differences from 0600 to 1100, 1100 to 1600, and 1600 to 0600 are shown diagrammatically in Fig. 1.

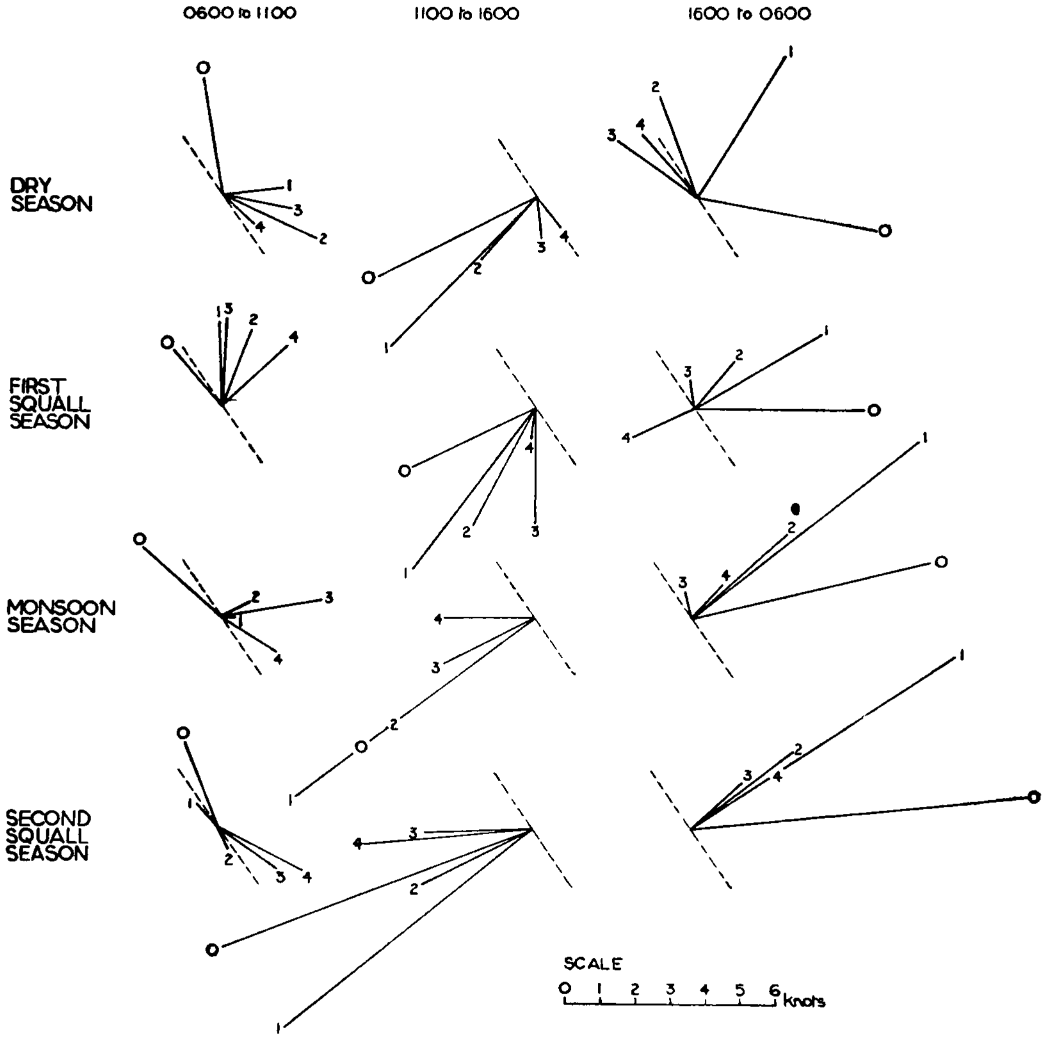


FIG. 1—MEAN VECTORIAL DIFFERENCES OF SURFACE AND UPPER WIND BETWEEN SUCCESSIVE OBSERVATIONS AT FREETOWN

Heights are given in thousands of feet at the end of each vector.
The broken lines show the general run of the coast.

The apparent diurnal variation of wind in the lowest few thousand feet, shown in Table I and Fig. 1, is presumably due to two main causes, *viz.* a land- and sea-breeze effect and " chance " variations which have not been smoothed out. The land- and sea-breeze effect can be defined as the variation which is due to relative changes of temperature and pressure over sea and land. The " effect " does not necessarily lead to an alternation of land and sea breezes; it may, for example, cause a weakening of a land wind during the day, or a sea wind at night. As the effect of chance variations is probably small near the surface, where there are most observations, the vectors can be used to determine the approximate direction of the land- and sea-breeze effects.

A sketch of the coast near Freetown is given in Fig. 2 which suggests that the sea-breeze effect will be from north or north-west if it is determined by the

TABLE I—VECTOR WINDS AT FREETOWN

Height	0600		1100		1600		No. of observations	0600		1100		1600		No. of observations
ft.	° true	kt.	° true	kt.	° true	kt.		° true	kt.	° true	kt.	° true	kt.	
	Dry season							Monsoon season						
4,000	45	3·0	67	3·3	85	3·7	111	48	1·2	94	2·6	180	0·2	16
3,000	303	2·0	32	0·9	130	0·8	166	234	2·2	129	1·3	217	2·7	22
2,000	287	4·7	276	1·8	246	3·7	200	232	5·2	230	4·2	231	9·1	38
1,000	285	3·9	300	2·4	244	6·9	221	236	4·1	233	3·9	233	12·4	51
0	205	1·7	325	2·1	264	5·7	221	167	1·7	273	1·7	242	7·3	52
	First squall season							Second squall season						
4,000	111	2·3	77	4·0	90	3·8	15	84	6·3	93	8·8	103	4·1	41
3,000	180	0·7	3	1·8	180	1·5	21	84	2·7	103	4·5	128	1·7	53
2,000	232	2·2	305	1·2	226	3·9	37	74	0·7	108	0·9	229	2·9	59
1,000	228	2·9	283	2·3	235	6·9	46	108	0·9	45	0·6	231	8·5	64
0	171	1·2	294	1·2	255	4·8	46	107	3·9	65	3·1	251	6·5	64

*The ascents were made at Falconbridge Point 8°30′N., 13°14′W.

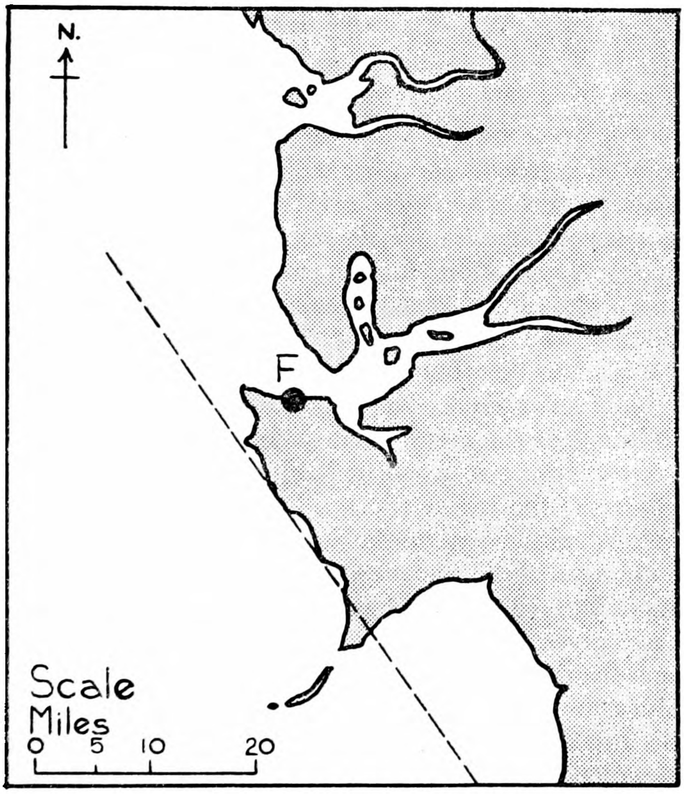


FIG. 2—POSITION OF FREETOWN IN RELATION TO THE RUN OF THE COAST

The broken line shows the run of the coast.

position of Freetown on the Sierra Leone peninsula, and from west or south-west if it is determined by the general run of the coast in this region.

From the data available, the best estimates of the direction of sea-breeze effect are given by the 1600 minus 0600 vectors, which can be obtained from Fig. 1 by reversing the 0600 minus 1600 vectors. In the dry season the surface sea-breeze effect is from north of west, in the first squall season it is from west, and in the other seasons from south of west. The direction of the sea-breeze effect at Freetown thus seems to be determined by general rather than local causes; this has also been found to be true for Scottish stations[1]*. The land- and sea-breeze effect can therefore be summarised by taking components normal to the general run of the coast in this part of west Africa. The components along the direction 235–55° are given in Table II, where positive values refer to winds blowing from sea to land.

TABLE II—COMPONENTS NORMAL TO THE COAST

Height	0600		1100		1600		0600		1100		1600	
ft.	*knots*											
	Dry season						Monsoon season					
4,000	−3·0	*−0·2*	−3·2	*0·0*	−3·2	*0·2*	−1·2	*−0·8*	−2·0	*2·1*	0·1	*−1·3*
3,000	0·7	*−1·5*	−0·8	*0·6*	−0·2	*0·9*	2·2	*−2·6*	−0·4	*3·0*	2·6	*−0·4*
2,000	2·9	*−1·5*	1·4	*2·2*	3·6	*−0·7*	5·2	*−1·0*	4·2	*4·9*	9·1	*−3·9*
1,000	2·5	*−1·5*	1·0	*5·8*	6·8	*−4·3*	4·1	*−0·2*	3·9	*8·5*	12·4	*−8·3*
0	1·5	*−1·5*	0·0	*5·0*	5·0	*−3·5*	0·6	*0·7*	1·3	*5·9*	7·2	*−6·6*
	First squall season						Second squall season					
4,000	−1·3	*−2·4*	−3·7	*0·6*	−3·1	*1·8*	−5·5	*−1·4*	−6·9	*4·2*	−2·7	*−2·8*
3,000	0·4	*−1·5*	−1·1	*2·0*	0·9	*−0·5*	−2·4	*−0·6*	−3·0	*2·5*	−0·5	*−1·9*
2,000	2·2	*−1·8*	0·4	*3·5*	3·9	*−1·7*	−0·7	*0·2*	−0·5	*3·4*	2·9	*−3·6*
1,000	2·9	*−1·4*	1·5	*5·4*	6·9	*−4·0*	−0·6	*0·0*	−0·6	*9·1*	8·5	*−9·1*
0	0·5	*0·1*	0·6	*3·9*	4·5	*−4·0*	−2·4	*−0·6*	−3·0	*9·3*	6·3	*−8·7*

*The changes from one observation to the next are shown in italics.

It is seen that in all seasons a land breeze is added to the 0600 wind between 0600 and 1100, except perhaps in the lowest few hundred feet in the first squall season and the monsoon season. This does not mean that the start of the sea-breeze effect is delayed until after 1100, but only that the total change between 0600 and 1100 adds a vector from land to sea. From 1100 to 1600 a sea breeze is added to the 1100 wind at all heights. Between 1600 and 0600 a land breeze is added to the 1600 wind; in the dry season and the first squall season this may be reversed at 3,000 or 4,000 ft.

During most of the year the mean wind in the lowest 2,000 or 3,000 ft. is from the sea at each observation; at 4,000 ft. it blows from the land. In the second squall season, however, the mean wind is from the land at all heights during the forenoon, and from the sea in the lowest 2,000 ft. during the afternoon.

The vectorial changes of the surface wind at Freetown are given in an earlier paper[2]. For comparison with Table I and Fig. 1 the values have been combined seasonally, and are given in Table III. The middle values for each season are the vector changes from 0600 to 1300.

The 0600 values for the 1942–44 and the 1944–46 series are very similar in the dry season and second squall season, and suggest that the data given for these seasons are more reliable than for the others. Assuming that in these seasons the surface data for the two periods are comparable, the vector changes from 1100 to 1300 and from 1300 to 1600 may give some indication of the time at which the sea-breeze effect is complete. In the dry season, the 1100–1300 change is 264° 3·0 kt. and the 1300–1600 change 227° 2·2 kt.; in the second

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*The index numbers refer to the list of references on p. 137.

TABLE III—SEASONAL VECTORS FOR SURFACE WIND AT FREETOWN, 1942–44

The vector changes are shown in italics

0600				1300		0600				1300	
° true	kt.	° true	kt.	° true	kt.	° true	kt.	° true	kt.	° true	kt.
		Dry season						Monsoon season			
215	1·7	*306*	*3·8*	283	4·2	203	1·7	*257*	*4·3*	243	5·5
		First squall season						Second squall season			
147	1·8	*290*	*6·7*	278	5·4	107	3·6	*275*	*6·7*	262	3·3

squall season the values are 254° 6·3 kt. and 240° 3·3 kt. As the first changes occur within 2 hr. and the second in 3 hr., it seems that either the sea-breeze effect is producing more rapid changes before 1300 than after it, or else the effect ceases fairly soon after 1300. More frequent observations would be necessary to determine which of these alternatives is correct. The data for the other seasons, although probably less reliable, lead to similar conclusions.

REFERENCES

1. GOLDIE, A. H. R.; Wind records from Bell Rock Lighthouse. *Geophys. Mem., London,* 7, No. 63, 1935.
2. HOGG, W. H.; The diurnal variation of surface wind at Bathurst, Freetown and Lagos. *Quart. J. R. met. Soc., London,* 72, 1946, p. 335.

PREPARATION OF LINEAR-FUNCTION TABLES ON A HOLLERITH TABULATING MACHINE

By D. DEWAR, B.Sc.

General principles.—During a lecture on mechanical computing methods at University College, London, the lecturer, Dr. Hartley, described how tables of a linear function could be produced on a Hollerith printer-tabulator.

The method is very simple. For a table such as the conversion of metres to feet successive multiples of 3·2808 are required together with the appropriate multiple. About 50 Hollerith cards are punched diagonally as shown in Fig. 1 (*i.e.* 1 in column 1, 2 in column 2, etc.) By suitable plug-board connexions a number punched in any card column can be printed in any space on a print bank. Insertion of decimals and editing have to be done afterwards. Connexions are made so that a 3 from column 3 is printed near the left-hand side of the sheet followed after a gap by a 2 from column 2, an 8 from column 8, an 0 from column 10 and another 8 from column 18. When the machine is set for progressive totalling it prints the accumulated total after the passage of each card and by connecting a device known as the card count it also prints the total of the number of cards that have passed through the machine. This card count is arranged to print to the left of the totals. As the pack of cards goes through the machine conversion values are printed as shown below:—

```
 1    3  2808
 2    6  5616
 3    9  8424
 4   13  1232
 ..  ..    ..
50  164   040
```

The pack is then run through the machine again to give values from 51 to 100 and the operation repeated until enough values have been obtained.

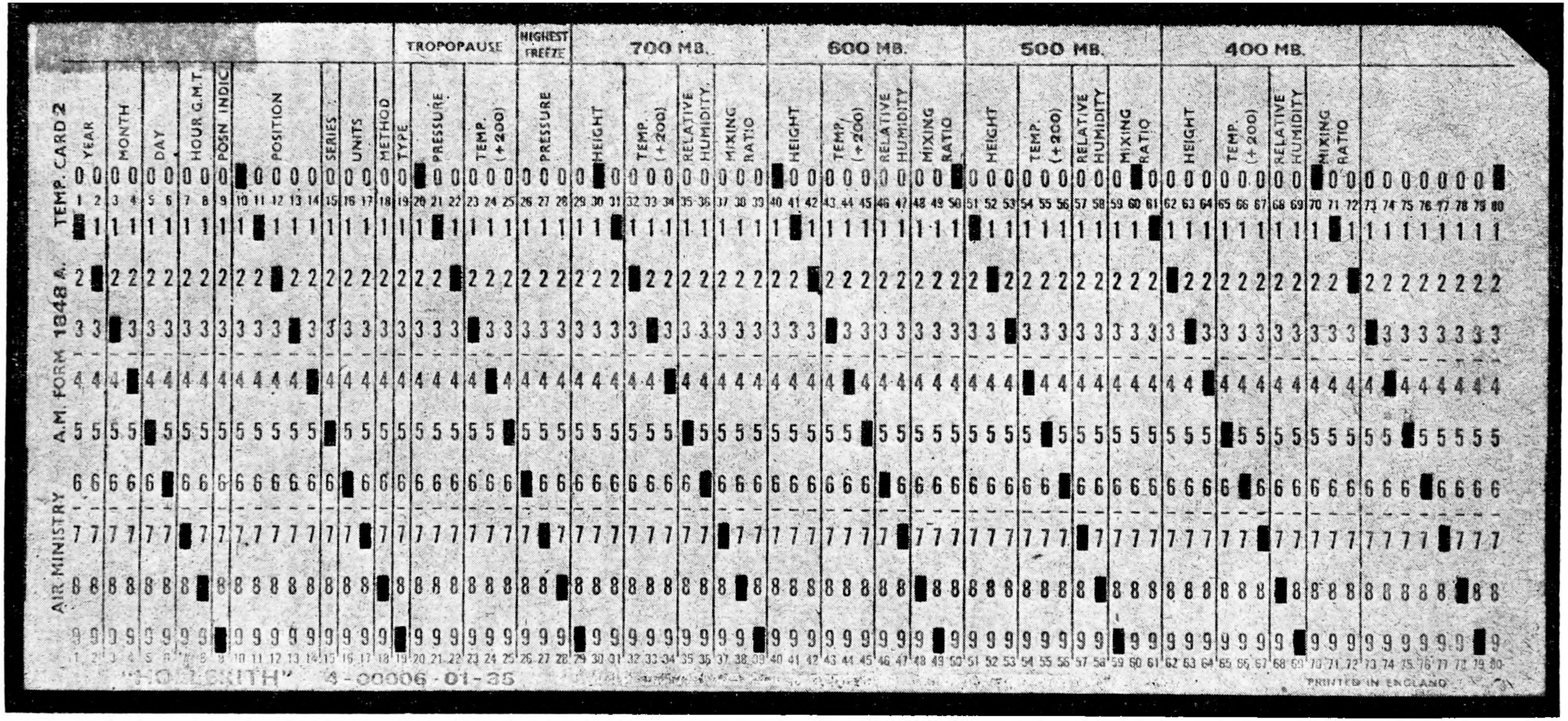
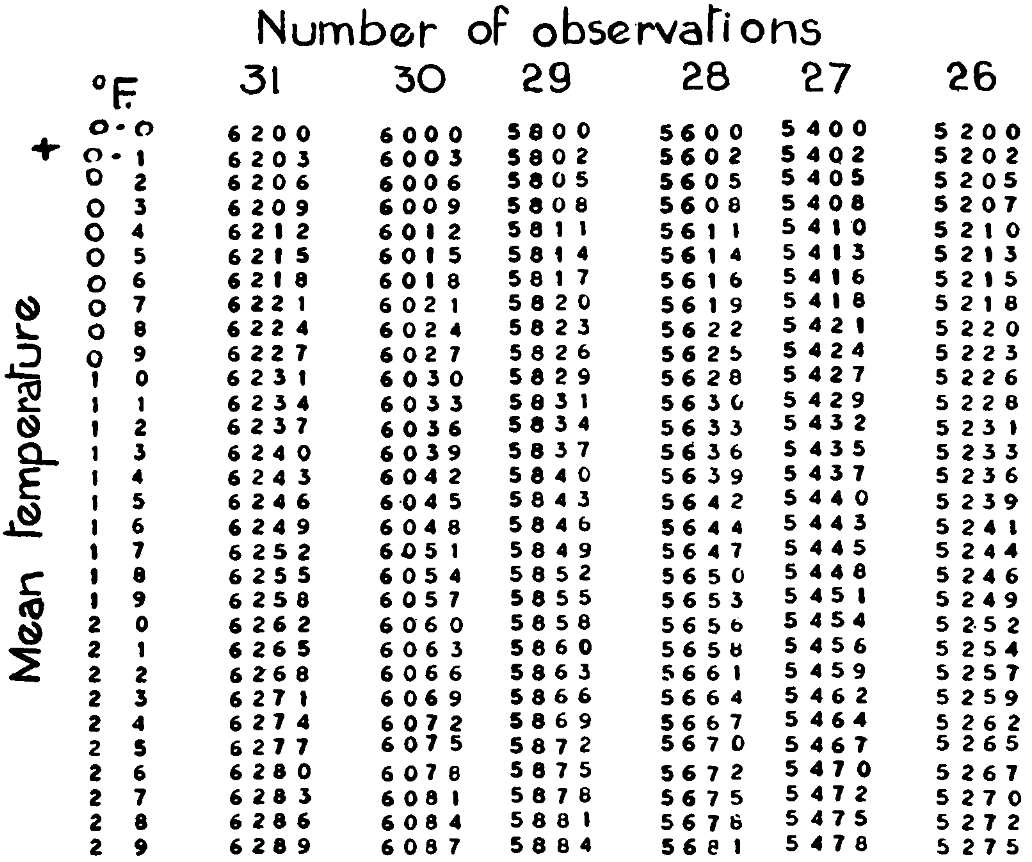

TEMP. CARD 2
A.M. FORM 1848 A.
AIR MINISTRY
YEAR
MONTH
DAY
HOUR G.M.T.
POSN INDIC
POSITION
SERIES
UNITS
METHOD
TYPE
TROPOPAUSE
PRESSURE
TEMP. (+200)
HIGHEST FREEZE
PRESSURE
700 MB.
HEIGHT
TEMP. (+200)
RELATIVE HUMIDITY
MIXING RATIO
600 MB.
HEIGHT
TEMP. (+200)
RELATIVE HUMIDITY
MIXING RATIO
500 MB.
HEIGHT
TEMP. (+200)
RELATIVE HUMIDITY
MIXING RATIO
400 MB.
HEIGHT
TEMP. (+200)
RELATIVE HUMIDITY
MIXING RATIO
"HOLLERITH" 4-00006-01-35
PRINTED IN ENGLAND

FIG. I—HOLLERITH CARD PUNCHED DIAGONALLY

For a single table such as this the required factor could, of course, have been punched successively on 50 cards; the object of the diagonal punching is to produce a pack of cards suitable for compiling any normal tables.

Application to upper air mean temperature tables.—When a start was made with the computation of monthly mean values of upper air temperatures from Hollerith cards it was soon found that though the totals of the daily values on the cards could be rapidly obtained on the tabulator a lot of time was being spent in working out means. The addition of 200 to the actual temperatures to eliminate minus values gave four-figure totals and incomplete observations gave varying divisors. It was evident that a lot of repetitive arithmetic would eventually be saved by producing suitable tables. The use of a tabulator to produce these tables made it practicable to do so. Owing to the large range of values and the varying number of observations 40,000 totals had to be given to cover the ranges 100° to −100°F. and 31 to 11 observations. It is doubtful if the production of such tables by clerical labour would have been worth while. A specimen of the tables is shown in Fig. 2. They were printed following the general principles described in the above paragraph. To get the first line of the table in Fig. 2 a suitably punched card was put through first. It will be noticed that the difference for some columns is not entirely constant; for the column headed 29, for instance, it is occasionally 0002. This is because an extra figure was used in the adding part of the machine to get greater accuracy but was suppressed at the printing stage. The figures in the body of the table are the totals as given by the tabulator and incorporate the 200 added to each individual



Number of observations

Mean temperature +

°F.	31	30	29	28	27	26
0·0	6200	6000	5800	5600	5400	5200
0·1	6203	6003	5802	5602	5402	5202
0 2	6206	6006	5805	5605	5405	5205
0 3	6209	6009	5808	5608	5408	5207
0 4	6212	6012	5811	5611	5410	5210
0 5	6215	6015	5814	5614	5413	5213
0 6	6218	6018	5817	5616	5416	5215
0 7	6221	6021	5820	5619	5418	5218
0 8	6224	6024	5823	5622	5421	5220
0 9	6227	6027	5826	5625	5424	5223
1 0	6231	6030	5829	5628	5427	5226
1 1	6234	6033	5831	5630	5429	5228
1 2	6237	6036	5834	5633	5432	5231
1 3	6240	6039	5837	5636	5435	5233
1 4	6243	6042	5840	5639	5437	5236
1 5	6246	6045	5843	5642	5440	5239
1 6	6249	6048	5846	5644	5443	5241
1 7	6252	6051	5849	5647	5445	5244
1 8	6255	6054	5852	5650	5448	5246
1 9	6258	6057	5855	5653	5451	5249
2 0	6262	6060	5858	5656	5454	5252
2 1	6265	6063	5860	5658	5456	5254
2 2	6268	6066	5863	5661	5459	5257
2 3	6271	6069	5866	5664	5462	5259
2 4	6274	6072	5869	5667	5464	5262
2 5	6277	6075	5872	5670	5467	5265
2 6	6280	6078	5875	5672	5470	5267
2 7	6283	6081	5878	5675	5472	5270
2 8	6286	6084	5881	5678	5475	5272
2 9	6289	6087	5884	5681	5478	5275

FIG. 2—TABLE FOR OBTAINING MEAN TEMPERATURES FROM HOLLERITH TABULATOR TOTALS

value. To find the mean for a given total the table is entered under the heading giving the appropriate number of observations, and after locating the total in this column the mean temperature is the value in the left-hand column in line with this total.

The tabulator can add and print each line of figures in about 0·6 sec. so the actual printing took about 40 min. Setting up and adjusting the lay-out made it a day's work, however.

The sheets obtained from the tabulator were then edited and sent to the Air Ministry Photographic and Reproductions Branch for copies to be made, each sheet being reduced to foolscap size. The tables have already been found a great convenience and should soon repay the time spent on their production.

CONVERSION OF PERCENTAGE FREQUENCIES OF FOG AND OF SLEET OR SNOW TO DAYS PER MONTH, AT SEA

By E. V. NEWNHAM, B.Sc.

The monthly meteorological charts for the oceans prepared by the Marine Branch of the Meteorological Office include charts on which lines of equal percentage frequency of gales, fog, sleet or snow, etc., are shown. For some purposes it is preferable to know the number of days per month on which the phenomenon occurs. The observing routine on ships keeping meteorological logs on which the charts are based—observations at 4 a.m., 8 a.m., noon, 4 p.m., 8 p.m. and midnight—does not make it possible to find out exactly what is required, but it is possible to relate percentage frequency to the average number of days per month on which the phenomenon occurs at one or more of these six hours of observation. In the case of fog this number is probably only very slightly less than the number of days with some fog, irrespective of the time of its occurrence, since it is probably exceptional for fog to occur without there being some at one or more of these six hours. In the case of sleet or snow the difference is probably rather larger, for on days with only a few brief snow flurries, snow may fairly often be absent at all the six hours of observation.

For a 30-day month the number of observations is 6 × 30 and the average number of observations of the phenomenon will be $6 \times 30 \times P$, where P is the percentage frequency. The average number of days per month on which the phenomenon occurs at one or more of the six hours of observation is clearly $180\ P/n$, where n is the average number of hours of observation out of the six on which the phenomenon is observed, on days when it is observed at, at least one of the hours.

Areas over which P for a given month was as nearly as possible constant were chosen, and n was obtained for each area by examination of the logs of all observing ships during the period when they were within that area in the appropriate month. The mean value of P was estimated from the lines of equal percentage frequency.

For fog, five areas which included the North Sea and various parts of the North Atlantic north of lat. 40°N. were selected, the month chosen being May, as this gave a sufficiently large number of fog days. The following figures were obtained:—

TABLE I

Percentage frequency	2½	5	11½	25	35
No. of fog days	50	50	38	31	65
n	2·26	2·24	2·34	2·74	3·66

For sleet or snow three suitable areas were found between 30°W. and 40°W., and 40°N. to 55°N. The period covered was December 20 – March 15. The following figures were obtained:—

TABLE II

Percentage frequency	5	9	13
No. of days with sleet or snow	32	38	54
n	2·7	2·6	2·3

Since it is unlikely that *n* really decreases as the percentage frequency increases, it is reasonable to attribute the above differences to lack of sufficient numbers of observations to give accurate means, and to assume that *n* is 2·50, the ratio of the total number of observations of sleet or snow (310) to the total number of days of snow (124). The figures for *n* in Table I are also subject to error, and an approximation to their true values was obtained by plotting *n* and the percentage frequency and drawing a smooth curve passing near to the points so obtained. In this way required values of *n* were obtained and the figures shown in Table III were calculated, to which have been added those for gales, which last appear on the monthly meteorological charts previously referred to.

TABLE III

Percentage frequency	1	5	10	15	20
Days per month of fog	1	4	8	11	14
Days per month of sleet or snow*	1	3–4	7	11	14–15
Days per month of gale	1	3–4	6–7	9	12

*The isopleths on the marine charts headed *Snow* (s) refer to occasions when the letter (s) had been logged, irrespective of whether it occurred in combination with r, signifying sleet, or without r, signifying snow. These isopleths therefore show frequency of snow or sleet taken together, and not snow.

TEMPERATURE AND HUMIDITY LAPSE RATES NEAR THE OCEAN SURFACE

By A. H. GORDON, M.S.

During the course of a voyage undertaken by Mr. O. M. Ashford of the Instruments Branch of the Meteorological Office and the author to station JIG in the ocean weather ship *Weather Recorder* in July 1948 opportunity was taken to make trial observations of the temperature and humidity lapse rates near the surface of the ocean by means of a balanced-bridge psychrometer. The observations were made by the following methods :—

(*a*) The psychrometer was hoisted up the side of the ship to the mast by a rope and pulley arrangement.

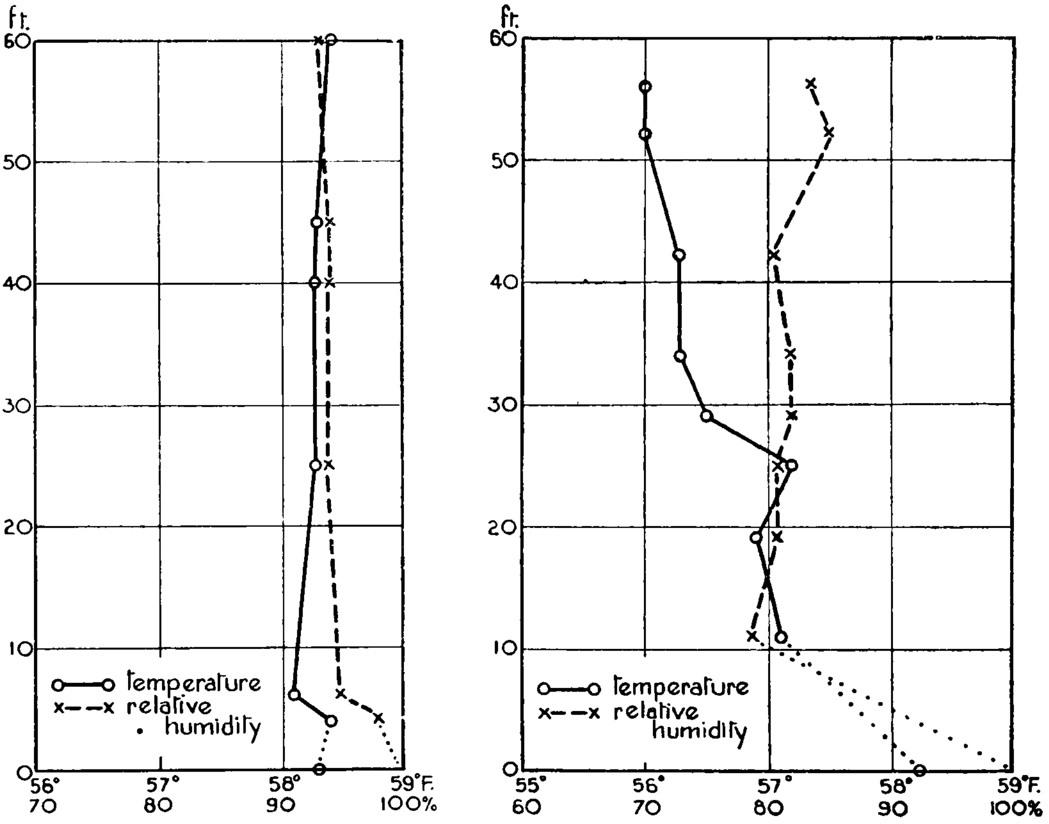
(*b*) The psychrometer was lifted by a tethered balloon controlled from a rubber dinghy a short distance away from the ship.

Method (*b*) could only be undertaken on occasions when the wind was force 3 or less and the state of the sea calm or slight.

These experimental trials proved quite successful so that arrangements were made by the Marine Branch of the Meteorological Office for their continuation aboard the ocean weather ships when weather conditions permitted. Some results of observations made during the course of a voyage to station JIG in July 1949 are now available and are shown in Figs. 1 and 2.

These three examples are representative of three distinct degrees of temperature lapse rate, superadiabatic, isothermal and inversion, respectively. In Fig. 1, method (*a*), the temperature decreases a degree Fahrenheit in 50 ft. approx. and the lapse rate is therefore superadiabatic within this layer. On this occasion station JIG was situated on the western edge of a ridge of high pressure. The wind had backed to WSW. force 3. The air mass was polar maritime and had travelled around the eastern side of the ridge from more northerly latitudes. This air was consequently cooler than the sea surface and comparatively dry.

In Fig. 1, method (*b*), the station was in a warm sector and the pressure gradient was weak. The wind was S. force 3. The air was returning polar maritime and was almost at the same temperature as the sea surface. The lapse rate was isothermal. The air in this case was undergoing a transitional period of modification as it changed from polar maritime to tropical maritime class.

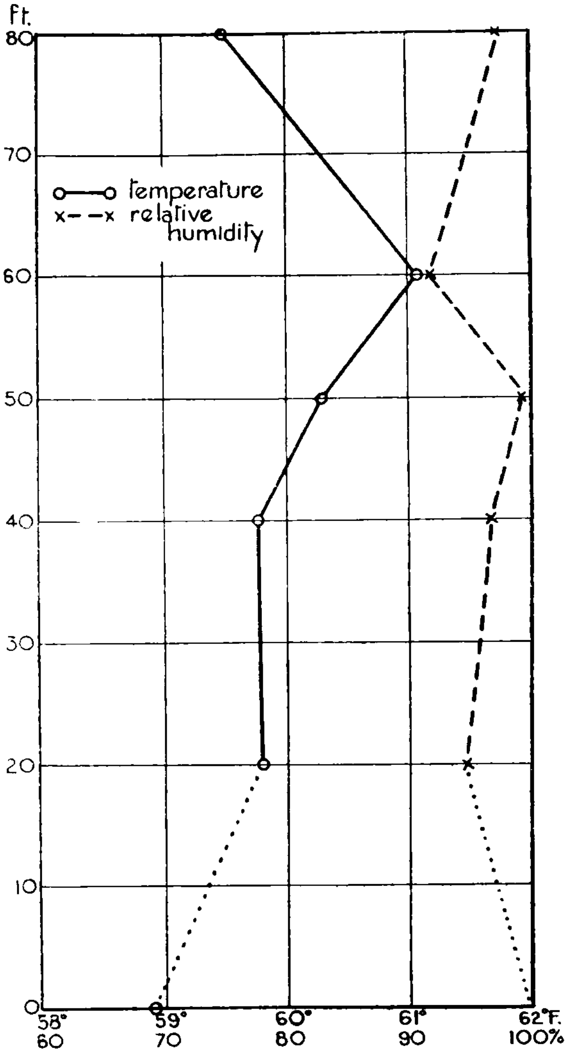


(a)
2000 G.M.T. July 18, 1949

(b)
1230 G.M.T. July 21, 1949

FIG. 1—LAPSE RATE OF TEMPERATURE AND HUMIDITY AT STATION JIG

In Fig. 2 the station was situated in tropical maritime air behind a warm occlusion. This air also appeared to be originally of polar maritime class. However, in this case the modification process had been carried much further so that the air could be termed tropical maritime when it covered station JIG. The air was warmer than the sea surface, and an inversion extended to 60 ft. above the sea surface above which the temperature commenced to decrease. The air was also much damper than in either of the other two cases.



(b)

1700 G.M.T. July 24, 1949

FIG. 2—LAPSE RATES OF TEMPERATURE AND HUMIDITY AT STATION JIG

It appears therefore that the temperature and humidity lapse rates near the ocean surface may provide a good criterion for the identification and classification of the existing air mass.

RADAR WEATHER ECHOES

By R. F. JONES, B.A.

Part II

The warm front by radar.—The generation of rain at the warm front of a depression has long been recognised as a much more gradual and wide-spread effect than the processes which take place at the cold front, and the radar evidence in no way contradicts this idea.

The typical P.P.I. picture (see photograph (*a*) of the series of photographs between pp. 144) of the precipitation associated with an active warm front is one of wide-spread and diffuse echoes with no clearly marked boundaries, and, although the intensity of the echo may be high, there are no indications of rapid variations in this intensity. The cores of high intensity, which are characteristic of the cold-front echo and which have been interpreted as evidence of localised strong vertical currents, are generally completely absent from the warm-front echo and the whole picture suggests a much more uniform precipitation rate over a much larger area.

The first indication of the approach of a warm front on the P.P.I. is the appearance on the display tube of weak and diffuse patches of echo at fairly short ranges (see photograph (*b*)) which are associated with the first detectable precipitation, not necessarily reaching the ground, from the altostratus sheet of the front. As the front continues its approach these weak and diffuse patches move closer to and past the station, while the heavier precipitation closer to the front begins to show up in the form of an echo which gradually increases in size and intensity (see photograph (*c*)). Further progress by the front brings the heavier precipitation across the station until the P.P.I. picture shows one large mass of echo more or less symmetrically distributed around the station and fading gradually with range (photograph (*a*)). The range at which the echo fades varies, of course, for each warm front, principally on account of the various rainfall intensities, but for an active warm front, with our equipment, the range is of the order of 30–50 miles. Such a picture may persist for some time depending on the width of the rain area associated with the front and the speed of movement of the front, but ultimately one notices a decrease in the range at which the echo fades in the direction of the front and the appearance of a more or less straight edge to the echo in this direction. This edge is not usually very clearly defined and marks the surface position of the warm front (photograph (*d*)). Behind this edge in the warm sector of the depression a few diffuse patches of echo sometimes persist, particularly in the neighbourhood of high ground where orographic precipitation is taking place, but even with very damp air in the warm sector and outbreaks of drizzle there is very little echo to be seen. It is noteworthy that the decrease in drop size from raindrops to drizzle drops is sufficient, with this equipment, to lead to a disappearance of the weather echo, at least beyond 10 miles, a fact which is not surprising when it is remembered that the received echo power is related to the sixth power of the drop diameters. Forced ascent of the warm air over high ground, however, leads to an increase in size of the waterdrops, and the occasional appearance of an echo in such areas. Therefore with a warm front as distinct from a cold front, the clearance of the weather echo does not necessarily indicate a break in the cloud or improvement in surface weather conditions but frequently only a decrease in drop size of the precipitation—a factor which actually leads frequently to a deterioration in surface conditions.

In the vertical cross-section the warm-front echoes are also seen to have a characteristic structure different from the typical cold front. The most outstanding characteristic is the appearance on almost every occasion of a bright band in the vicinity of the freezing level, while the remainder of the echo has a diffuse appearance and is free from marked columns or clear-cut edges (see photograph (*e*)). As mentioned earlier the bright band occurs in conditions of low vertical-current speeds and has been explained as coming from melting ice crystals or snow-flakes[1]* An alternative explanation has been proposed by Byers and Coons[2]. With either of these explanations it can be said that the echo above the bright band is almost certainly received from large ice crystals or snow-flakes while with equal certainty the echo from beneath the bright band comes from raindrops. In some of the weaker warm fronts only

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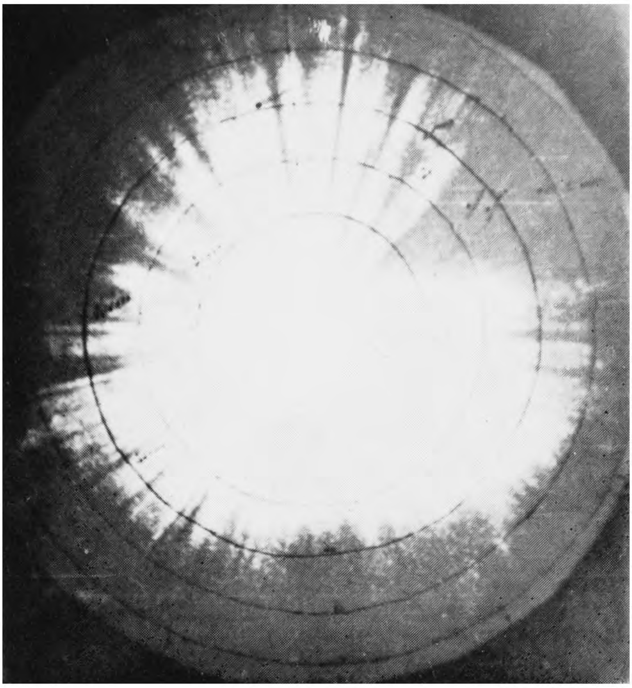
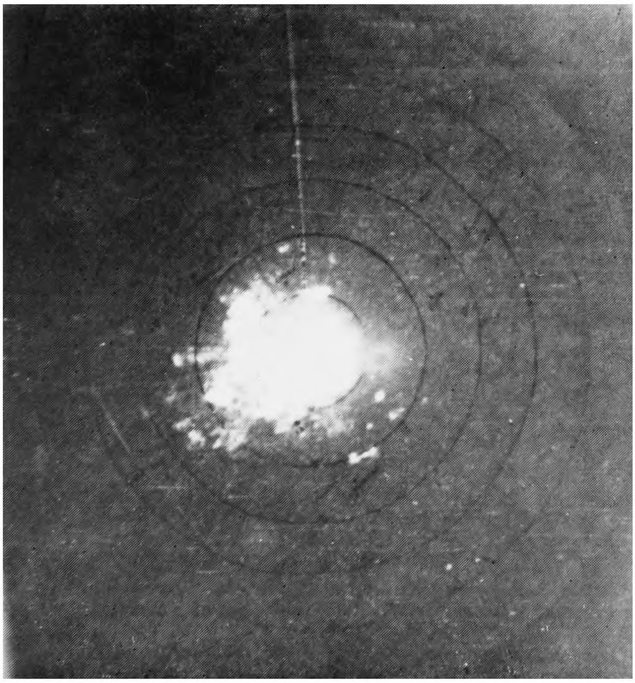
*The index numbers refer to the list of references on p. 145.



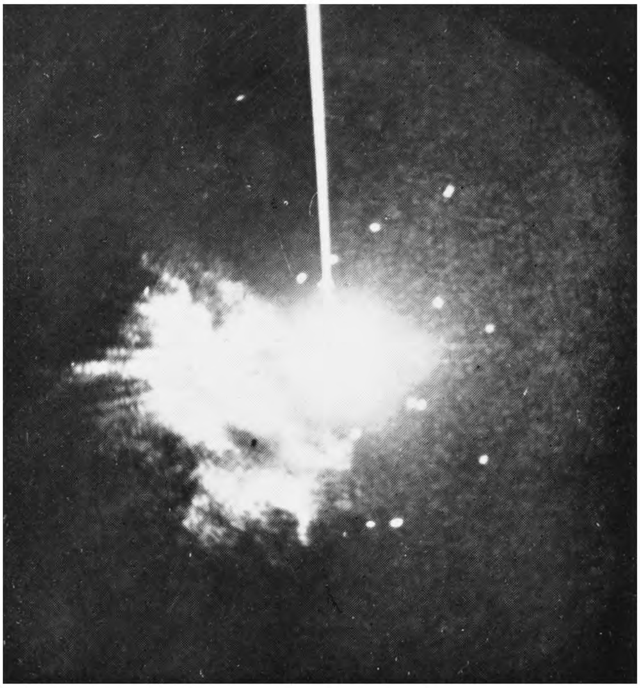
(*a*)



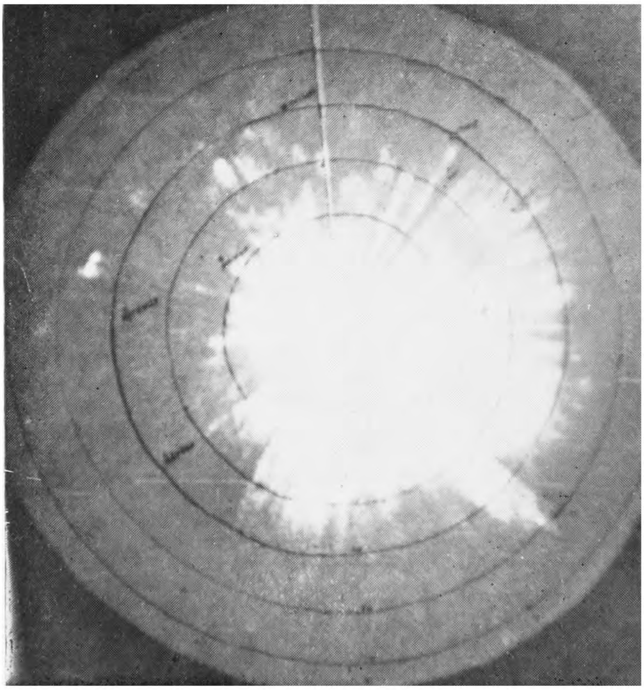
(*b*)

WARM FRONT BY RADAR

(see p. 143)



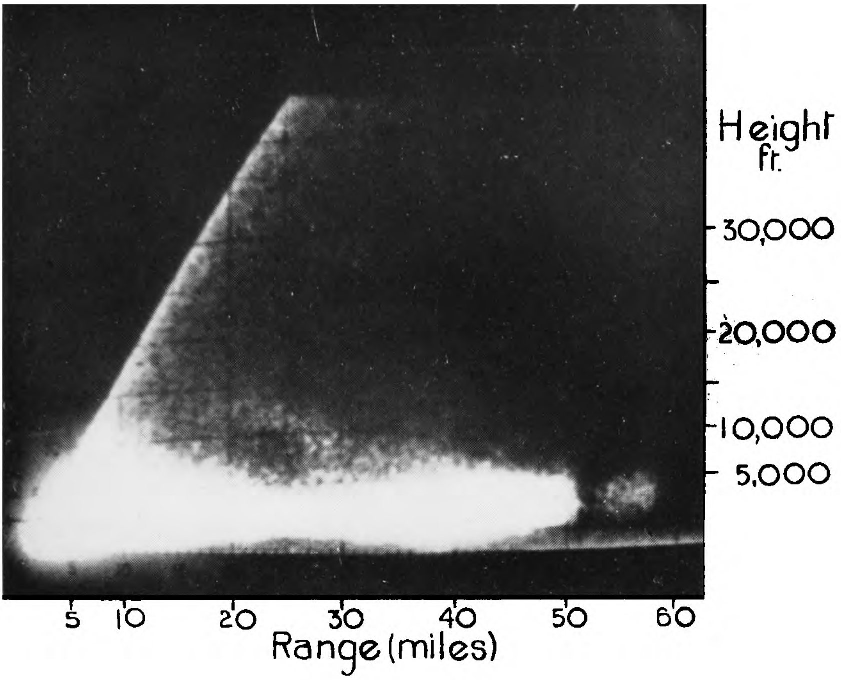
(*c*)



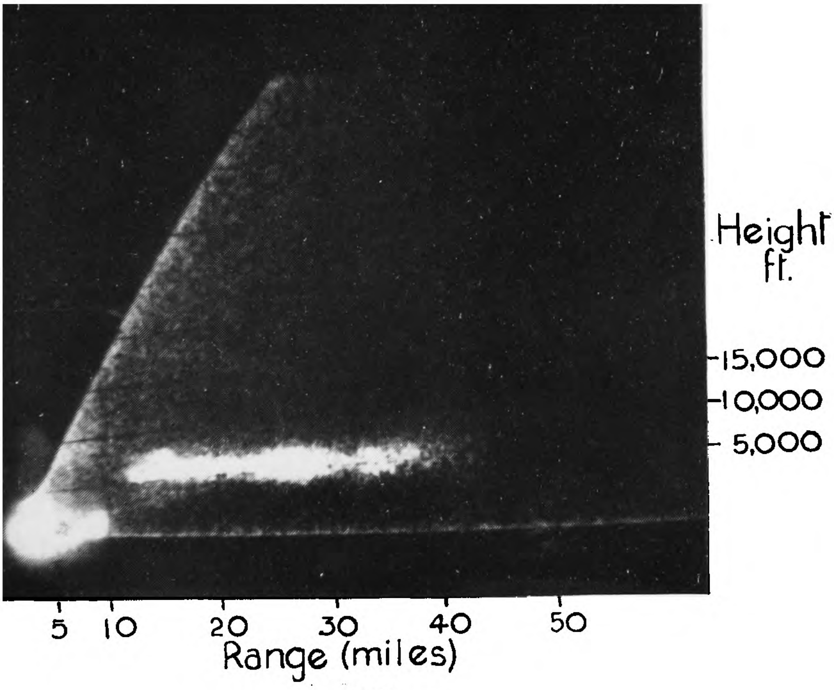
(*d*)

WARM FRONT BY RADAR

(see p. 143)



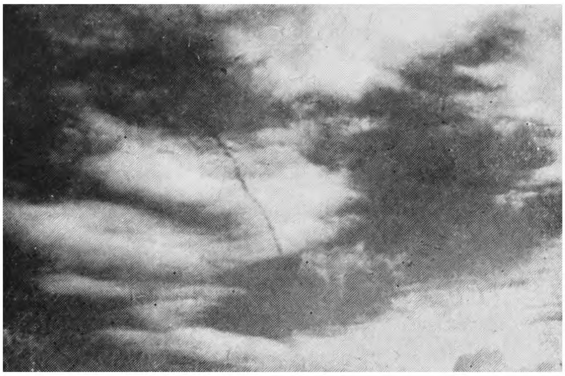
(*e*)



(*f*)

WARM FRONT BY RADAR

(see p. 143)



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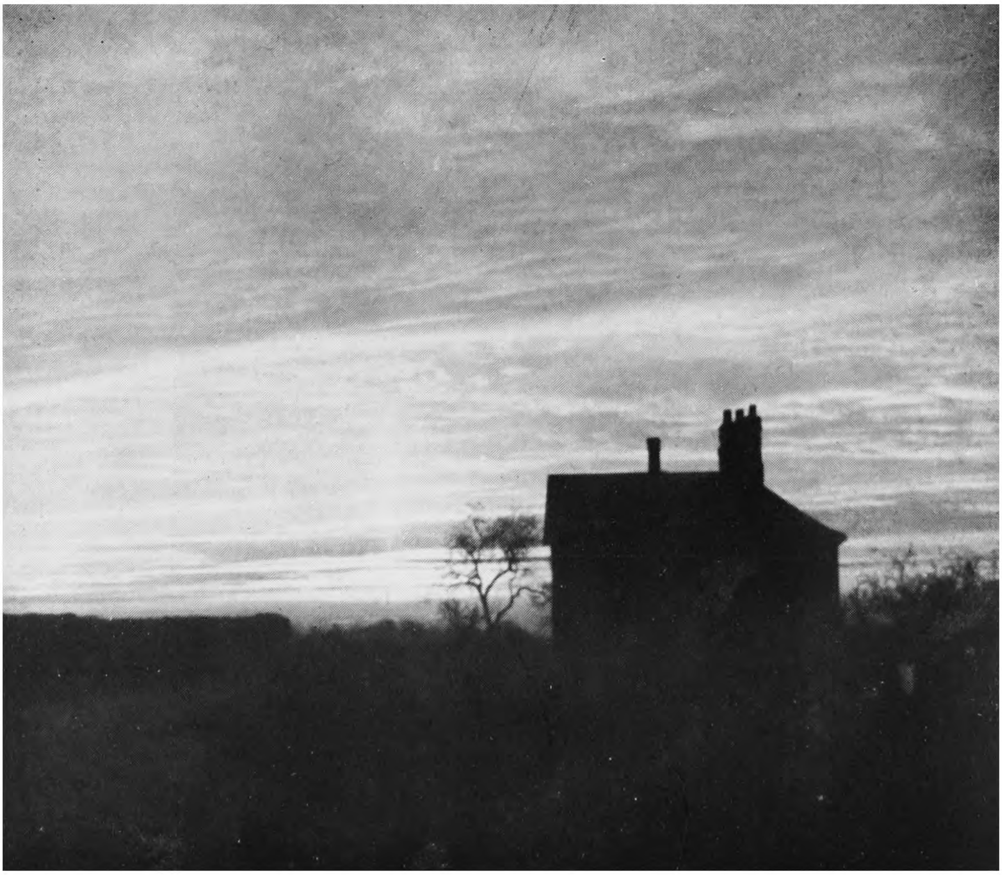
CLEAR LANE CUT IN ALTOCUMULUS BY AN AIRCRAFT

(see p. 153)



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SUN PILLAR AT WEST RAYNHAM, 1630 G.M.T., JANUARY 21, 1950

(see p. 153)

the bright-band echo is visible (photograph (*f*)). The diffuse nature of the echo above the bright band and lack of well marked edges has been interpreted as evidence of weak but wide-spread upward currents with little or no turbulence[3].

Once more it can be stated that the radar evidence is in agreement with the generally accepted idea of the warm-front precipitation as being due to the slow and uniform ascent of the air over a wide area.

Further details of the photographic illustrations and their interpretation follow below:—

Photograph (*a*).—This photograph was taken at 1030 G.M.T. on April 23, 1947. The circular black markers are at 10-mile intervals from the radar set which is situated, of course, at the centre of the picture. The first easily discerned marker is at a range of 20 miles. The single radial black line is along magnetic north. The gaps in the echo along radial lines from the station are not due to variations in the precipitation rate but to screening of the radio energy close to the transmitter by trees. Note the gradual fading of the echo with range.

Photograph (*b*).—This was taken at 0923 G.M.T. on April 23, 1947, *i.e.* the same warm front as in photograph (*a*). The echoes inside the first 10-mile marker are from permanent echoes due to high ground, but the echoes to the west are the first signs of the precipitation from the approaching warm front.

Photograph (*c*).—This photograph was taken at 1623 G.M.T. on December 6, 1948. The bright radial line is along magnetic north. Range markers are not visible on the photograph but the furthest bright echo to the west is from about 45 miles (the echo extends weakly to about 50 miles). There is a weak diffuse echo over the station which partly hides the permanent echoes, and comes from the initial light precipitation of the front. The bright spots of echo are from aircraft.

Photograph (*d*).—This is again associated with the same frontal precipitation as in photographs (*a*) and (*b*) and was taken at 1324 G.M.T. Note how the range to which the echo extends has decreased to the west and north-west and the appearance of an ill-defined edge lying approximately north-east to south-west about 20 miles from the station.

Photograph (*e*).—This H.R.T. photograph was taken at 1248 G.M.T. on March 4, 1949, on a bearing of 290° true. Note the bright band of echo centred at about 2,500 ft. extending to 50 miles, and the diffuse nature of the echo above this band. The freezing level was 3,500 ft. at Larkhill at 0900 G.M.T. falling eastwards to 2,000 ft. at Downham Market.

Photograph (*f*).—This H.R.T. photograph was taken at 1202 G.M.T. on January 15, 1949, on a bearing of 357° true. It is associated with a rather weak and slow-moving warm front and only the bright band in the vicinity of the freezing level is visible.

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METEOROLOGICAL OFFICE DISCUSSION

The Discussion, held at the Imperial College on March 13, 1950, and opened by Mr. J. S. Sawyer, dealt with the formation and behaviour of secondary depressions on warm fronts, cold fronts and occlusions.

Mr. Sawyer referred to a discussion held two years ago at which Dr. R. C. Sutcliffe advocated the use of charts of the thickness of the 1000–500-mb. layer as a tool in forecasting practice[1]*. A series of investigations into the formation and behaviour of secondary depressions has since been carried out at the Central Forecasting Office, Dunstable, and an attempt has been made to relate their occurrence to features of the thickness pattern. The results of the study of secondary depressions on warm fronts and occlusions has already been summarised in the *Meteorological Magazine*[2], but the investigation of cold-front waves has not yet been published.

The investigations have been primarily empirical; occasions of the formation of secondary depressions have been noted and the corresponding thickness pattern examined on a thickness chart of the 1000–500-mb. layer. It was found possible to identify thickness patterns characteristic of the formation of secondaries on warm fronts and warm occlusions, and also on cold occlusions. These have already been described[2]. It had not been possible to establish any particular thickness pattern as characteristic of cold-front waves, although many formed between 200 and 600 miles east of a trough line in the thickness pattern. Dr. Sutcliffe[3] has shown theoretically how cyclonic and anticyclonic development can be related to the thermal wind field and thickness pattern. The results of the investigations of secondary depressions were consistent with these ideas. Warm-front and warm-occlusion secondaries were found to form to the right of a confluence in the thermal wind field, and the cold-occlusion secondaries were found to the left of a diffluence. Both of these areas should be cyclogenetic according to Sutcliffe's theory. Moreover, charts had been drawn presenting the numerical evaluation of the expression derived by Sutcliffe for the cyclonic development, *viz.*—

$$-\left\{V'\frac{\partial\zeta'}{\partial s}+2V'\frac{\partial\zeta_0}{\partial s}\right\}$$

in which V' is the thermal wind speed,

ζ' is the vorticity of the thermal wind,

ζ_0 is the vorticity of the surface geostrophic wind field, and

$\partial/\partial s$ denotes differentiation in the direction of a thickness line.

Cyclonic maxima of this expression had shown a close association with secondary development.

An examination of all the cold-front waves which formed over Europe and the eastern Atlantic during the course of a year has revealed the following facts:—

(*a*) none formed on cold fronts less than 1,200 miles long;

(*b*) many of the waves appeared to be the result of the distortion of the front either by hills or by neighbouring pressure systems;

(*c*) of the remainder, 26 out of 31 formed in areas classified as cyclogenetic by inspection on the basis of Sutcliffe's theory.

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*The index numbers refer to the list of references on p. 149.

The polar-front theory of depressions treats the wave depressions as unstable oscillations of the front, and Solberg[4] has shown mathematically that unstable disturbances of the right type and dimensions should exist. If this point of view is correct we should not expect to predict the exact time or place for the formation of a wave, and the best that can be expected is a criterion which will indicate whether a front is unstable or not. The mathematical treatments of waves on fronts show that there is a lower limit to the wave-length for which waves are unstable, and the fact that there seems to be a sharp lower limit of 1,200 miles on the length of a front capable of forming waves might be regarded as conforming with the instability theory. However, the fact that some other cause for wave formation appears to exist in respect of nearly all waves seems to be against any theory depending on instability alone. The apparent cause may be either kinematic, as when the front is distorted by neighbouring pressure systems or by hills, or it may be dynamic, as when there is a "cyclonic-development" area associated with a maximum of Sutcliffe's expression.

Perhaps we can resolve these points of view by regarding the front as unstable, but the growth of individual waves so slow that they cannot start as infinitesimal perturbations.

A finite disturbance has to be set up if the wave is to become of significant amplitude before it runs out of the frontal belt.

The work on cold-front waves seems to suggest or confirm the following rules for forecasting:—

(1) If a cold front extends over a length of 1,200 miles or more and is associated with a 25-kt. thermal wind (1000–500 mb.) over this length, a new wave should be expected on it.

(2) New waves should not be inserted on shorter fronts, or on fronts not fulfilling condition (1).

(3) On fronts satisfying condition (1) the wave may be expected to develop:—

(*a*) where the front is subject to orographic distortion;

(*b*) where a bulge in the front can be produced by a flow round adjacent pressure systems;

(*c*) where the thermal vorticity term is maximum (often 200 to 600 miles east of a thermal trough line).

(4) Both thermal wind and the direction of the warm-sector isobars are a good guide to the direction of motion of a newly formed wave.

(5) The speed of a newly formed wave is not closely related to the thermal wind speed—probably four fifths of the geostrophic wind speed in the warm sector is a reasonable estimate.

The Director said that the importance of secondary developments was emphasised by the fact that, in an analysis of errors in forecast charts prepared at the Central Forecasting Office, one third of all significant errors could be attributed to such new formations.

Dr. Farquharson said the characteristic thickness patterns of secondary depressions were often referred to in forecast discussions at the Central Forecasting Office. Their application to forecasting was limited by the need to anticipate the development of the thickness pattern itself, and by the difficulty of fixing precisely the time of formation and track of the secondary, both of which have a considerable influence on the weather forecast. The vorticity computations referred to by Mr. Sawyer could not be applied to forecast charts as such charts were not sufficiently accurate for the purpose. Dr. Farquharson also asked whether the jet stream was essential to the formation of occlusion secondaries or merely incidental—Mr. Sawyer thought it was an important factor.

Mr. Harley (London Airport) quoted developments in the 24 hours before the meeting as a good example of the value of thickness patterns in forecasting.

Mr. Zobel said that he had obtained only very limited success in the use of thickness patterns in forecasting. He quoted February 8 and 21, 1950, as occasions when developments were contrary to indications of the thickness pattern.

Mr. Lamb inquired if there was any method of applying the results in regions such as the Southern Oceans for which no upper air observations were available. He remarked that the formation of waves through distortion of fronts by influence of neighbouring pressure systems was a well tried forecast tool. He also asked if small stable waves were not found on fronts less than 1,200 miles long. Mr. Sawyer, in reply, said that waves of length less than 200–300 miles had been excluded from the analysis.

Mr. Scorer (Imperial College) remarked that theoretical studies of unstable atmospheric waves, such as those due to Dr. Eady, might provide much knowledge as to how the energy of translation is transformed into energy of rotation, and also regarding potential energy changes in depressions.

Mr. Lumb referred to the formation of secondary depressions in the lee of the Alps. In these, the cold front crossed the mountains and moved ahead as an upper cold front. The subsequent development of the lee depression took place behind the front, and was more closely associated with the distortion of the wind and thermal fields by the mountains than with the front itself.

Miss Carruthers remarked that statistically the relation between secondaries and the thickness pattern appeared to be highly significant.

Mr. Illsley remarked that the suggested application of thickness patterns to forecasting was more difficult at local meteorological offices with limited resources than it was at the central office. He also suggested that the ideas be tested on charts drawn in some service where the thickness pattern was not being used as a forecasting tool in this way.

Mr. Galloway referred to recent work in America which suggested that a major contribution to surface pressure changes came from the sub-stratosphere. He thought a level above 500 mb. would be more significant than those used in the present investigations. He also referred to the gravitational effects of masses of air. In reply, Mr. Sawyer considered that great caution was necessary in attributing the cause of pressure changes to specific layers on account of density changes; convergence of air at one level was nearly always balanced by divergence in another and the changes in a vertical column were only a small residual.

Mr. Bannon pointed to the approximations in the derivation of the basic equations of Sutcliffe's theory. He thought its failures occurred when the omitted factors were significant.

Dr. Sutcliffe remarked that most of the omitted terms were zero if no development were taking place. He thought, therefore, that the derived expression was a legitimate criterion of development. In the past, theoretical meteorologists had been content to concentrate on the explanation of what the synoptic meteorologist observed. Now, however, there were signs that the theorists were moving ahead; his own work[3] and more recently that of Charney[6] had predicted features of the atmospheric flow not previously recognised by the empiricists. In 20 years' time progress in meteorology may be from the theoretical to the practical instead of the reverse.

Secondary depressions appear to be slow moving at first but subsequently move more quickly; they appear to need to attain a finite size before they break away; there is an analogy with eddies forming in the lee of an obstacle.

The application of vorticity methods needs much experience because third-order differentials are involved; it is desirable to extend charts over a wide area.

The Director, summing up, said that despite its limitations he considered the technique of the use of thickness patterns in the manner described was extremely important. It provided a means by which synoptic meteorology could escape from the bondage of empiricism.

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METEOROLOGICAL RESEARCH COMMITTEE

The ninth meeting of the Physical Sub-Committee of the Meteorological Research Committee was held on February 16, 1950.

The Chairman's report to the Committee was discussed and the Sub-Committee also formulated recommendations for the revision of Part III of the Research Programme.

The view of the Sub-Committee on the desirability of including on the tephigram saturated adiabatics for liquid water at temperatures below 0°C. had been sought, and the Sub-Committee recommended in favour of doing this.

Papers considered included one dealing with the horizontal dimensions of cumulonimbus clouds by R. F. Jones[1], based upon radar observations and one dealing with the size of cloud particles by A. C. Best[2].

[1] *Met. Res. Pap., London*, No. 535. [2] *Met. Res. Pap., London*, No. 538.

OFFICIAL PUBLICATIONS

Manuals of Meteorological Practice

A number of manuals and handbooks are in course of compilation which describe in considerable detail the technical procedure and practice followed within the Meteorological Office. Among them are the " Manual of Meteorological Observing " and the " Manual of Meteorological Instruments ". The first of the series to be completed is the " Manual of Meteorological Statistics " which has been written by Dr. C. E. P. Brooks and Miss N. Carruthers. This book has been sent for printing and it is hoped that copies will be available by the autumn of 1950. A short abstract of the Manual follows.

Manual of meteorological statistics

This Manual is in three parts. Part I deals with the nature of observations, the study of frequency distributions of different climatic elements, significance tests and the construction of normal values. Part II discusses the relations between two or more variables, correlation, smoothing, and the fitting of curves to observed data, and includes a chapter on vectors with special reference to winds. In Part III the authors deal with time-relations in meteorology. This includes the " persistence " of a phenomenon from one observation to the next, harmonic analysis and various methods of searching for hidden periodicities. The illustrations and examples are drawn almost entirely from meteorological sources.

The following publications have recently been issued:—

PROFESSIONAL NOTES

No. 99—Possible effects of heavy rain on aircraft. By J. S. Sawyer, M.A.

Heavy rain may produce downward air currents by frictional drag, or by cooling the air and making it denser than the surrounding air. An aircraft might also experience a downward thrust in rain on account of the weight of the rain or the impact of the drops. In this note the relative importance of these effects is examined.

It is concluded that the most important factor in producing downward air currents in rain is the cooling of the air by the evaporation of the drops. The effect of frictional drag of the drops is much smaller, except during exceptionally heavy rain. The direct effect of the impact or weight of the rain on the aircraft is negligible.

No. 100—Prediction diagram for radiation fog. By W. C. Swinbank, B.Sc.

Radiation fog is caused by the cooling of the surface air below the dew point. Cooling is aided by clear skies and by conditions of calm, when there is no tendency for eddy transfer of heat in the vertical. A high dew point requires the retention of the water vapour already present in the surface layer or an increase by diffusion downwards. These conditions require a small or negative decrease of vapour pressure with height, or " hydrolapse ". The occasions of wide-spread or local fog and of no fog, over south-east England in October and November 1936–41 were plotted against the square of the wind shear (measured as the difference between wind speed at the surface and the gradient wind) and the hydrolapse, and it was found possible to distinguish three regions—wide-spread fog, local fog and no fog. Prediction of fog by this diagram was improved by adding a supplementary diagram, introducing depression of dew point below dry bulb temperature. A similar diagram was constructed for Lincolnshire and Yorkshire. It was also found possible to relate the time of formation of fog, in hours after sunset, to the same factors.

METEOROLOGICAL REPORT

No. 5—Aviation meteorology of the route Castel Benito—Cairo

This report describes the climate of the air route from Tripolitania to Lower Egypt from the point of view of aviation. The movement of depressions and fronts and the associated weather on the various sections of the route are described. Visibility, cloud, wind, rainfall, etc., are discussed individually for the different seasons of the year. A number of climatic tables are given.

Much of the air route lies over desert areas and fine weather predominates. Probably the most important interruptions to flying on the route are due to the occasional wide-spread sandstorms which occur chiefly in the winter and spring. Settled fine weather is experienced in summer. In winter, although fine weather predominates, there are periods of showery weather with local thunderstorms. These disturbed conditions are appreciably more frequent over the western part of the route than over the eastern section.

ROYAL METEOROLOGICAL SOCIETY

The meeting of the Society on February 22, 1950, Dr. R. C. Sutcliffe in the chair, was devoted to the subject of radar echoes from cloud and precipitation.

The meeting opened with a short film from the records of the Massachusetts Institute of Technology, presented by Dr. Wexler. The film was composed of photographs of the height-range indicator tube taken at intervals during a period of precipitation and speeded up to show the development and movement of the weather echoes. Mr. Hooper then read the following paper.

J. E. N. Hooper and A. A. Kippax—"The bright band—a phenomenon associated with radar echoes from falling rain".

Mr. Hooper showed that when frontal rain is viewed with a vertically-looking radar, using a wave-length of 3 cm., echoes are received which exhibit a characteristic layer of greater intensity near the freezing level. Observations made at Larkhill at the same time as the radio-sonde ascents enabled the height of this layer or " bright band " to be determined relative to the freezing level, and it was shown that the bright band lies on the average 330 ft. below the freezing level, with a probable error of 150 ft. The explanation of the bright band due to Ryde* leads one to expect that the ratio of bright-band intensity to the intensity of the echo from the rain beneath will be equal to the ratio of the terminal velocities of a raindrop to those of a snow-flake of equal mass. Observations of the terminal velocities of snow-flakes made by the authors and others were described, and it was shown that the ratios of the terminal velocities of raindrop and snow-flake so obtained were in the same range of values as the ratio of echo intensities from the bright band to those from the rain below.

Mr. R. F. Jones then opened the general discussion on radar echoes by describing some of the investigations which had been made at East Hill. Evidence had accumulated to support the belief that temperatures at the tops of weather echoes are an indication of the relative strengths of the vertical currents within the echoes. Thus thunderstorm echoes usually extended to temperatures around −40°F. or below while the tops of echoes associated with the weak up currents of layer clouds and weak fronts did not reach to temperatures colder than 16°F. Two types of echo were indicated, the bright-band echo from layer and frontal cloud and the cumulonimbus echo which appeared as a strong column of echo without bright-band characteristics. This lead to a theory that the echoes from cumulonimbus clouds were from raindrops at all heights, and he suggested that growth to raindrop size in such clouds occurred by coalescence and condensation without the aid of an ice crystal.

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*RYDE, J. W.; The attenuation and radar echoes produced at centimetre wavelengths by various meteorological phenomena. Physical and Royal Meteorological Societies' report on " Meteorological factors in radio-wave propagation ". London, 1946, p. 169.

A lively discussion followed in which Messrs. Mason, Wexler, Browne, Galloway, Ludlam and others took part. The mechanism of ice-crystal aggregation to form snow-flakes, the possibility of wet hail rather than water-drops as the explanation of the cumulonimbus echo and the question whether the bright band was not after all present, although at times in a very weak form, in cumulonimbus clouds were among the many points raised. Mr. E. Gold stressed the point that radar has provided a powerful new tool for the meteorologist.

Brief replies to the discussion were made by Messrs. Jones, Hooper and Kippax but time did not permit of detailed replies.

LETTER TO THE EDITOR

Relation between number of days with 0·4 in. or more of rain and total rainfall

You may like to have a few additional details about the relation between the number of days with 0·4 in. (10 mm.) or more and the total rainfall, discussed by Mr. Newnham in the *Meteorological Magazine* for January 1950. When this question first came up in 1941, the idea of comparing number of days with 0·4 in. or more with total rainfall rather than with number of days with 0·01 or 0·04 in. was arrived at by simple reasoning and checked by correlation, but I was agreeably surprised by the magnitude of the correlation coefficients. These were:—

	No. of stations	Winter	Spring	Summer	Autumn	Year
Western and northern Europe	19	+0·97	+0·92	+0·93	+0·98	..
British Isles	18	..	..	..	..	+0·984
Norway	34	..	..	..	..	+0·985
Southern South America	5	..	..	..	..	+0·998

The first and last of these groups included stations in a wide variety of climates. The regression equations for the annual values all approximated to the form:—

$$\text{Days with } 0{\cdot}4 \text{ in. or more} = R-c$$

where R is measured in inches, but the value of c varied from 6 in South America to 12 in the British Isles. It is evident from Mr. Newnham's Fig. 1 that this relation extends to months as well as seasons.

It may be of interest to add that in the British Isles:

$$\text{Days with } 0{\cdot}2 \text{ in. or more} = 1{\cdot}5R+6$$

where R is in inches. For days with rainfall above 0·5 in. this type of relation no longer holds.

January 30, 1950 C. E. P. BROOKS

NOTES AND NEWS

Clear lane cut by aircraft in altocumulus

We are indebted to Mr. J. Paton for drawing attention to the photograph shown facing p. 145, and to the photographer and owner Mr. J. F. Steljes for permission to print it. The photograph shows a clear lane left in altocumulus cloud by the precipitation of ice crystals after the passage of an aircraft through the cloud*. The precipitation was presumably caused by artificial nucleation of the supercooled droplets. The photograph was taken at Edinburgh at 0945, March 30, 1944.

The south of Scotland on the morning in question was in a cold northerly air stream giving broken cumulonimbus clouds with snow showers. The altocumulus in which the lane was cut was almost certainly of the cumulogenitus type.

Sun pillar at West Raynham

The photograph of a sun pillar facing p. 145, was taken by Mr. J. D. Hastings at West Raynham, Norfolk, at 1630 G.M.T., January 21, 1950, using Ilford Pan. F. film and an exposure of one tenth sec. at F.2·9. The time of sunset was 1621 G.M.T.

The synoptic situation was as follows: on Saturday, January 21, 1949, a belt of high pressure extended from Scandinavia to the British Isles with two centres, one over south central Norway and the other off north-east England. A warm front at midday from the Danish-German border to an approximate position 58°N. 03°E. was making steady south-west progress, and by 1800 G.M.T. was lying from north-west Holland to about 58°N. 42°E. At 1500 G.M.T. medium cloud ahead of it had reached the coast of East Anglia and south-east England, altocumulus-altostratus was reported by Felixstowe, Manston and Lympne; Yarmouth reported altocumulus castellatus. Altocumulus-altostratus was reported by West Raynham in the 1600 G.M.T. observation. The Downham Market winds for 1400 G.M.T. gave directions and speeds of 70–80°, 15–20 kt. The warm front was in itself weak, but the arrival of warmer moister air in East Anglia just ahead of, and behind, it gave very bad weather during the night and the following day with fog, very low cloud and drizzle.

REVIEWS

The Geology of Water Supply, by Sir Cyril S. Fox. 10 in. × 6½ in., pp. x + 209. *Illus.* The Technical Press Ltd., London, 1949. Price 25*s*. 0*d*.

The book is one of a series planned by the Technical Press Ltd. to deal with hydrographic surveys for the storage of water resources, the treatment of water for purification and softening, the disposal of waste water and sewerage, and the erection of waterworks for towns. The author covers a wide field, including the

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*See last paragraph of the article on " Artificial nucleation of clouds " by R. Frith, in the *Meteorological Magazine* for January, 1950, p. 9.

meteorological and geological factors affecting the availability of the water on the surface of the land or underground.

The book is well produced and sets out in simple language the fascinating details of the supply and disposal of water. It is a timely publication because of the present interest in water supply, arising in this country from the inconvenience of recent droughts and of catastrophic floods, as in the Tweed Valley in August 1948. It is a traveller's account of the subject, based on the author's thirty-six years' experience, mainly in India and Pakistan, so that many of the references to the literature are for places abroad, and some for not very recent dates.

The first five chapters deal with the subject from the aspect of general physical geography, the remaining four chapters are on surface water supplies, underground water supplies, engineering works and the quality of water. Of the nine chapters the second, " Rainfall considerations ", is concerned with meteorological aspects, the distribution of rainfall, the effects of marshes and forests, evaporation, percolation and absorption, yield of catchments, etc.

Adequately to cover so large a subject as rainfall in 31 pages is not easy, but a surprising selection of information has been given. A page has been devoted to the Beaufort scale of wind force, but the equivalent forces in miles per hour as given are not those now in general use (see the " Meteorological Observer's Handbook, 1942 "). The statement against Beaufort force 2 for winds at sea reads " Light breeze, 1 to 2 knots ", whereas the full specification of the Meteorological Office distinguishes between land, sea and coast, and for coast reads " Wind fills the sails of smacks which then travel at about 1–2 miles per hour." The equivalent velocities at a standard height of 33 ft. above open flat ground are 4–6 kt. or 4–7 m.p.h.

On p. 9 and p. 11 the author gives the annual rainfall over the land surface of the earth as roughly 30 in. It does not detract from the general argument, that there is a tremendous volume of rain, to find (in *Memoirs of the Royal Meteorological Society* No. 28 and the discussion) that the most recent determination is nearer 26 in.; the sea being much wetter with 47 in.

J. GLASSPOOLE

Statistisch Onderzock naar de Samenhang Tussen het weer, de Grasproductie, en de Melkaanvoer. By Dr. Ir. J. Past. Koninklijk Nederlandsch Meteorologisch Instituut No. 102. Mededeelingen en Verhandelingen, Serie A, No. 55. 9½ in.×6¾ in., pp. 119. 's. Gravenhage, 1949. 3.00 florins. Dutch with English summary.

This publication is an account of the research carried out under the auspices of the Royal Meteorological Institute at De Bilt, into the statistical relations between weather, grass production and milk supply.

Important positive correlations were found between grass production, cloudiness and number of days with precipitation in May and June; similar correlations in July and August were found between milk production and these weather parameters. The temperature correlation was negative in this period.

The importance of this work was strikingly exemplified by the serious drop in milk production in Great Britain after the sunny dry summer of 1949, and again stresses the need for a correct distribution of available water for agricultural and urban needs.

L. P. SMITH

OBITUARY

It is with regret that we announce the death of Mr. and Mrs. John Bell Beck at the Observatory, Eskdalemuir, on March 8 and 10, 1950, respectively. Both were unexpected and occurred after very brief illnesses.

Mr. Beck joined the staff at the Observatory as a boy clerk in 1913, and it was not very long before he showed the qualities necessary for a good observer and recorder; he was careful, conscientious, painstaking and honest; indeed in 1919 he succeeded Mr. P. N. Skelton as chief magnetic observer, a post in which such qualities are essential.

During the last 30 years most of the magnetic work of the Observatory has largely been dependent on his skill and assiduity as an observer, and to him must be attributed a large part in the building up of the esteem with which Eskdalemuir magnetic work is regarded throughout the world.

Apart from a period of service with the army in The Royal Scots Fusiliers and the Cameron Highlanders in World War I and a visit towards the end of 1921 to Shetland to assist with the starting of magnetic observations at Lerwick Observatory, Mr. Beck spent all his service career at the Observatory, Eskdalemuir. Indeed, his long experience in all sides of Observatory work was of inestimable value to successive superintendents as he was the connecting link in the Observatory's history. His presence as such a link might have passed, as it were, without notice—his character being so unassuming—but his absence will be felt.

In private life, Mr. Beck took an active part in local affairs; he was an active supporter of the local branch of the British Legion; a keen bowler, and as a violinist or " fiddler " of no mean order was much in demand for local functions such as concerts and dances. His wife, also of a quiet and unassuming nature, played an unobtrusive part in local matters. They will be very much missed in the Valley of the Esk. Mr. and Mrs. Beck leave behind a son, William Robert, known to most as " Billy ".

METEOROLOGICAL OFFICE NEWS

Postings of assistants.—To many assistants, postings may appear to be made without any consideration for their wishes and domestic circumstances. This is far from being the real state of affairs, and assistants are invited to consider the reasons why postings cannot be avoided.

As a background to the problem it is necessary to remember that the total number of assistants required for the Meteorological Office is, at present, between 1,250 and 1,300. This establishment is deployed at 156 different units in the United Kingdom, 22 units overseas, and 4 Ocean Weather Ships, besides the three Headquarters locations in London, Harrow and Dunstable. Whenever a vacancy occurs at any of these units it is necessary to consider making a posting in order to maintain a strength which will suffice to meet the commitments of the State Meteorological Service. In most cases vacancies cannot be filled directly by the recruitment of new staff because of the length of training required.

The principal reasons why vacancies arise are :—

(1) Promotion of assistants,

(2) Call-up of assistants for National Service,

(3) Opening of new offices,
(4) Tours of duty in Ocean Weather Ships and overseas,
(5) Release of airmen from National Service,
(6) Resignation of assistants.

As far as possible all such vacancies are filled from a pool comprising :—

(1) Assistants reinstated on return from National Service,
(2) Airmen under training,
(3) Newly appointed assistants.

Assistants reinstated after National Service and newly appointed assistants who are under military age, are posted to units as close as possible to the location of their choice. If a vacancy occurs at a Royal Air Force station in a locality which is not amongst those selected by assistants in these two categories it is the general practice to post an airman. It thus comes about that airmen tend to be posted a little more frequently than their civilian counterparts. Generally speaking, less hardship is imposed on an airman by a posting than on a civilian assistant because airmen do not have to worry about finding accommodation at the new unit. But it would be a mistake for airmen to suppose that the frequency of posting to which they are subject whilst in uniform will continue when they are reinstated as civilians.

It is exceptional for postings of established assistants, other than on purely temporary duty, to be made for any but the following reasons :—

(1) To provide further experience and so improve prospects for promotion,
(2) To obtain promotion or special responsibility allowances,
(3) For study purposes,
(4) On request.

An intensive effort is being made, by forward planning, to avoid posting civilian assistants except for the reasons stated above, and at the same time to restrict postings of airmen to a minimum.

Prospects of promotion for assistants.—A question of great importance for every member of staff is : " What are my prospects in the Meteorological Office?" For assistants, many of whom are unestablished and whose minds are not yet firmly made up about the choice of a career, the answer to that question is vital.

Some recent letters of resignation suggest that assistants probably take too pessimistic a view of their chances of promotion from Assistant to Senior Assistant. At the present time there are sufficient posts to allow the promotion of every assistant whose experience and qualifications merit consideration : but it is realised that in the future the ratio of posts in the grades of Senior Assistant and Assistant will fail to provide sufficient opportunity to all those assistants whose qualifications are too restricted for them to enter the Experimental Officer class. For this reason plans have already been made to increase the ratio over the next few years.

It is quite exceptional to make a statement about staffing policy until it is possible to implement it. This information is given, however, because it is important that assistants should not be led to resign in ignorance of their prospects.

Ocean Weather Ships.—Dr. C. E. P. Brooks has kindly presented a travelling set of chessmen to the Ocean Weather Ships. The chess experts in the Ships are going to compete against each other for possession of this little trophy.

New Meteorological Observer's Handbook.—The present Meteorological Observer's Handbook was originally issued in 1908 as a successor to books of instruction written by Sir H. James (1851) and Dr. Scott (1875). The instructions for observing were brought up to date in successive editions, but no drastic changes in the general style and arrangement of the book have hitherto been made. The last edition appeared in 1939 and the need for revision became pressing after the Conference of Directors at Washington in 1947. It had also become evident that a re-arrangement of contents and considerable recasting was necessary to serve the varied needs of both climatological and synoptic stations. The Handbook has therefore been almost entirely rewritten and it is hoped that copies will soon be available for issue.

Courses for Meteorological Observers.—Four courses for Meteorological Observers were recently held at the Meteorological Office Training School. They were attended by Observers from Health Resort stations, Crop Weather stations and Climatological stations. The courses lasted for 2½ days and covered the making and recording of observations and the lay-out, care and maintenance of instruments. At the end of each course a visit was made to the Climatological Division at Harrow.

There is no doubt that both the Meteorological Office and the Observers themselves have much to gain from these courses and appreciation is due to the various authorities who made it possible for their observers to attend.

Sports activities.—Mr. W. C. Williams, Scientific Assistant at No. 1 (M.E.) Meteorological Unit, Ismailia, has captained the local R.A.F. team in another successful season.

Besides winning the Egypt Cup for the second season running, R.A.F. Ismailia have scored 169 points against 11 in their nine league matches : they lost only two friendly games, and one in the Canal North Cup. Mr. Williams plays scrum half, and is acknowledged to have a fine flair for the game.

THE WEATHER OF MARCH 1950

Mean pressure was slightly above 1020 mb. from Poland south-westwards across Germany, central and northern France, western Spain and Portugal to Madeira, and also between Bermuda and the Bahamas and over an area in Canada situated west of Hudson Bay and extending from about latitude 50°N. to 70°N. It was slightly below 1000 mb. over small areas between northern Norway and Spitzbergen and south of Greenland, and also over the Aleutian Islands. Departures from normal were not large ; there was an excess of 2 to 7 mb. over most of Europe and a deficit of about the same amount over most of the northern part of the North Atlantic west of about longitude 20°W.

Over the British Isles the weather was mild; it was dry except in an area extending northward from the Isle of Man and the Cumberland coast across Lanarkshire, in the neighbourhood of Skye and in a coastal belt in east Scotland.

In the opening days of the month pressure was high from Scandinavia to France, while troughs of low pressure moved north-east over the north-west districts of the British Isles ; rain occurred, chiefly in the west and north (2·70 in. at Blaenau Festiniog, Merioneth on the 2nd), but it was bright, with frost early, in eastern and midland districts of England on the 1st. Gales occurred locally in the extreme north of Scotland on the 1st–4th. On the 4th the Azores anticyclone moved north-east and subsequently became established over southern England and central Europe; a period of fair, warm weather, apart from considerable fog night and morning, ensued. Day temperatures were high from the 5th or 6th to the 8th, reaching 60°F. locally, and touching 66°F. at Croydon on the 8th. On the 9th a shallow depression moved east-south-east across Scotland giving slight local rain.

Subsequently high pressure became established in a belt from Greenland to the Bay of Biscay, while a depression off west Norway moved south and then south-east. Mainly dry, colder weather prevailed in the British Isles, with local sleet or snow from about the 11th–14th; a screen minimum temperature of 18°F. was registered at Eskdalemuir on the 14th.

A change to a mild, unsettled type set in on the 14th, when a deep Atlantic depression moved east-north-east towards the west of Ireland and troughs of low pressure crossed the British Isles. The main centre eventually moved north-east to the neighbourhood of Thorshavn and another very deep depression in mid Atlantic moved slowly north-east ; on the 17th a small secondary developed off south-west Ireland and moved quickly north-east across the British Isles and was associated with local thunderstorms. Throughout the period 14th–19th rain fell daily and was heavy locally, particularly in the north-west on the 18th (2·49 in. at Peden Reservoir, Lanarkshire, 2·25 in. at Ruthwell, Dumfriesshire and 2·20 in. at Borrowdale, Cumberland). Gales were registered at exposed places on the 16th–18th. From the 20th–23rd other shallow secondaries developed and crossed the country giving further rain at times.

Subsequently the Azores high moved north-east to the Baltic and later an anticyclone on the Atlantic moved to a position westward of the British Isles and a period of anticyclonic weather occurred, with morning fog. On the 30th and 31st shallow troughs moving south-east caused some slight rain in the northern half of the country.

The general character of the weather is shown by the following provisional figures :—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ..	67	15	+3·7	60	−5	109
Scotland	65	17	+3·6	91	−3	96
Northern Ireland ..	62	26	+3·8	65	−6	111

RAINFALL OF MARCH 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ..	·53	29	*Glam.*	Cardiff, Penylan ..	2·18	69
Kent	Folkestone, Cherry Gdn.	1·09	50	*Pemb.*	St. Ann's Head ..	2·35	66
,,	Edenbridge, Falconhurst	1·39	56	*Card.*	Aberystwyth	1·50	55
Sussex	Compton, Compton Ho.	2·57	93	*Radnor*	Tyrmynydd	2·99	56
,,	Worthing, Beach Ho.Pk.	1·23	64	*Mont.*	Lake Vyrnwy	3·34	74
Hants	Ventnor, Roy. Nat. Hos.	1·28	62	*Mer.*	Blaenau Festiniog ..	6·89	80
,,	Bournemouth	1·35	58	*Carn.*	Llandudno	1·14	56
,,	Sherborne St. John ..	1·18	53	*Angl.*	Llanerchymedd ..	2·75	93
Herts.	Royston, Therfield Rec.	·48	26	*I. Man.*	Douglas, Borough Cem.	3·54	120
Bucks.	Slough, Upton	·65	37	*Wigtown*	Port William, Monreith	2·83	99
Oxford	Oxford, Radcliffe ..	·87	53	*Dumf.*	Dumfries, Crichton R.I.	4·33	145
N'hant.	Wellingboro', Swanspool	·71	40	,,	Eskdalemuir Obsy. ..	6·85	140
Essex	Shoeburyness	·58	43	*Roxb.*	Kelso, Floors	1·67	86
Suffolk	Campsea Ashe, High Ho.	·53	32	*Peebles*	Stobo Castle	3·57	123
,,	Lowestoft Sec. School ..	·33	20	*Berwick*	Marchmont House ..	1·80	68
,,	Bury St. Ed., Westley H.	·42	22	*E. Loth.*	North Berwick Res. ..	2·07	110
Norfolk	Sandringham Ho. Gdns.	·74	39	*Midl'n.*	Edinburgh, Blackf'd. H.	2·20	112
Wilts.	Bishops Cannings ..	·91	40	*Lanark*	Hamilton W. W., T'nhill	3·46	124
Dorset	Creech Grange.. ..	1·91	68	*Ayr*	Colmonell, Knockdolian	2·14	63
,,	Beaminster, East St. ..	2·74	94	,,	Glen Afton, Ayr San ..	3·80	90
Devon	Teignmouth, Den Gdns.	1·57	60	*Bute*	Rothesay, Ardencraig	3·31	92
,,	Cullompton	2·08	76	*Argyll*	L. Sunart, Glenborrodale	4·51	81
,,	Ilfracombe	2·08	72	,,	Poltalloch	2·63	68
,,	Okehampton, Uplands	2·83	68	,,	Inveraray Castle ..	5·32	84
Cornwall	Bude, School House ..	1·40	57	,,	Islay, Eallabus ..	2·36	62
,,	Penzance, Morrab Gdns.	2·59	81	,,	Tiree	3·35	100
,,	St. Austell	2·46	72	*Kinross*	Loch Leven Sluice ..	2·97	99
,,	Scilly, Tresco Abbey ..	1·61	61	*Fife*	Leuchars Airfield ..	2·39	123
Glos.	Cirencester	1·56	68	*Perth*	Loch Dhu	6·65	101
Salop.	Church Stretton ..	1·21	50	,,	Crieff, Strathearn Hyd.		
,,	Cheswardine Hall ..	1·51	71	,,	Pitlochry, Fincastle ..	2·09	76
Worcs.	Malvern, Free Library	1·48	76	*Angus*	Montrose, Sunnyside ..	2·09	100
Warwick	Birmingham, Edgbaston	1·56	82	*Aberd.*	Braemar	2·27	76
Leics.	Thornton Reservoir ..	·86	47	,,	Dyce, Craibstone ..	2·82	106
Lincs.	Boston, Skirbeck ..	·60	38	,,	Fyvie Castle	3·61	133
,,	Skegness, Marine Gdns.	·39	24	*Moray*	Gordon Castle	1·99	86
Notts.	Mansfield, Carr Bank ..	·98	47	*Nairn*	Nairn, Achareidh ..	1·19	65
Derby	Buxton, Terrace Slopes	2·47	60	*Inverness*	Loch Ness, Garthbeg ..	2·34	70
Ches.	Bidston Observatory ..	1·30	68	,,	Glenquoich	7·98	82
Lancs.	Manchester, Whit. Park	1·82	81	,,	Fort William, Teviot ..	5·69	85
,,	Stonyhurst College ..	2·00	54	,,	Skye, Duntuilm ..	5·32	121
,,	Blackpool	1·64	69	*R. & C.*	Tain, Tarlogie House ..	1·03	46
Yorks.	Wakefield, Clarence Pk.	1·75	97	,,	Inverbroom, Glackour..	3·45	69
,,	Hull, Pearson Park ..	1·07	59	,,	Applecross Gardens ..	5·06	109
,,	Felixkirk, Mt. St. John	1·03	52	,,	Achnashellach	6·18	91
,,	York Museum	·98	58	,,	Stornoway Airfield ..	3·44	88
,,	Scarborough	·82	46	*Suth.*	Loch More, Achfary ..	5·97	93
,,	Middlesbrough.. ..	·67	43	*Caith.*	Wick Airfield	2·61	115
,,	Baldersdale, Hury Res.	1·52	49	*Shetland*	Lerwick Observatory ..	3·36	106
Norl'd.	Newcastle, Leazes Pk. ..	·53	26	*Ferm.*	Crom Castle	2·43	78
,,	Bellingham, High Green	1·26	43	*Armagh*	Armagh Observatory ..	1·08	46
,,	Lilburn Tower Gdns. ..	1·11	42	*Down*	Seaforde	1·91	65
Cumb.	Geltsdale	2·21	79	*Antrim*	Aldergrove Airfield ..	1·31	52
,,	Keswick, High Hill ..	3·77	84	,,	Ballymena, Harryville..	1·86	59
,,	Ravenglass, The Grove	4·10	133	*L'derry*	Garvagh, Moneydig ..	2·12	68
Mon.	Abergavenny, Larchfield	2·55	84	,,	Londonderry, Creggan	2·31	72
Glam.	Ystalyfera, Wern House	4·83	90	*Tyrone*	Omagh, Edenfel ..	2·42	77

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, NOVEMBER 1949

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION		BRIGHT SUNSHINE		
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1008·3	−5·6	57	27	49·1	38·7	43·9	+0·1	41·5	90	5·0	2·16	−0·06	17	2·2	24
Gibraltar	1017·0	−1·0	84	46	68·8	56·2	62·5	+2·5	57·8	82	4·2	6·10	—	7	6·3	62
Malta	1013·9	−2·0	72	52	67·7	58·3	63·0	−0·9	59·5	70	4·6	4·74	—	15	6·9	68
St. Helena	1015·9	−0·6	69	53	64·3	54·4	59·3	+0·6	55·0	95	7·8	1·29	+0·05	15	—	—
Lungi, Sierra Leone	1011·7	—	89	71	86·4	73·5	79·9	—	75·2	87	5·9	4·49	—	9	7·1	—
Lagos, Nigeria ..	1010·5	+0·4	94	68	89·3	71·5	80·4	−1·3	78·4	85	6·6	2·92	—	8	7·0	59
Kaduna, Nigeria ..	1009·4	—	95	53	92·0	60·4	76·2	−1·7	63·8	37	3·9	0·00	−0·21	0	9·5	82
Chileka, Nyasaland	1012·1	−1·0	98	62	91·2	70·3	80·7	+3·0	67·5	54	3·5	1·60	−2·22	7	8·2	64
Lusaka, Rhodesia ..	1009·9	−0·2	101	62	88·4	65·8	77·1	+2·9	63·5	55	5·2	2·61	−1·62	15	7·1	55
Salisbury, Rhodesia	1011·0	−0·6	94	56	83·3	61·9	72·6	+2·4	61·1	53	4·0	2·54	−1·48	9	7·3	57
Cape Town	1015·0	−0·8	86	51	72·6	57·7	65·1	+0·7	55·9	60	3·8	1·23	+0·14	8	—	—
Palmietfontein, S. Africa	1011·7	—	88	45	76·4	54·2	65·3	—	56·6	64	4·0	6·83	—	13	8·6	—
Mauritius	1015·2	−0·9	90	59	84·7	66·0	75·3	−0·2	66·2	60	4·0	2·30	+0·54	12	8·8	68
Calcutta, Alipore Obsy	1013·3	−0·1	89	56	84·1	62·2	73·1	−0·4	65·2	62	1·0	0·00	−0·65	0	9·7	87
Bombay	1012·1	+0·1	94	69	90·3	71·9	81·1	+0·5	70·7	69	0·6	0·00	−0·45	0	10·2	91
Madras	1012·4	+1·1	89	66	85·2	71·4	78·3	−0·6	72·8	80	4·3	6·93	−6·68	7	8·9	77
Colombo, Ceylon ..	1010·7	+0·7	90	70	86·4	73·5	79·9	−0·1	74·9	84	4·2	9·70	−2·06	13	8·0	68
Singapore	1009·6	+0·2	91	72	85·9	74·3	80·1	−0·5	76·2	85	6·2	9·64	−0·27	16	4·3	36
Hongkong	1017·4	−0·2	85	55	74·9	65·8	70·3	+0·7	64·9	76	—	5·09	+3·35	10	6·1	55
Sydney, N.S.W. ..	1012·7	−1·1	90	50	73·7	60·2	66·9	−0·1	62·1	65	4·5	3·45	+0·60	11	8·1	58
Melbourne	1012·3	−2·1	85	46	69·1	52·0	60·5	−0·8	55·2	63	6·7	5·51	+3·28	17	4·5	32
Adelaide	1013·9	−1·4	94	42	71·1	54·1	62·6	−4·4	55·8	57	7·0	1·93	+0·79	13	5·3	38
Perth, W. Australia	1013·7	−1·7	96	50	76·6	56·8	66·7	+0·6	59·7	64	4·0	1·49	+0·69	10	8·7	63
Coolgardie	1013·1	−0·3	92	46	80·4	53·2	66·8	−3·9	58·6	55	3·4	1·74	+1·15	7	—	—
Brisbane	1013·8	−0·8	91	56	80·7	64·8	72·7	−0·8	65·2	65	4·4	4·52	+0·79	13	8·6	67
Hobart, Tasmania ..																
Wellington, N.Z. ..	1012·8	+0·8	71	41	61·8	48·6	55·2	−0·4	52·3	72	5·2	4·52	+1·00	11	7·0	49
Suva, Fiji	1011·0	−0·1	87	66	82·8	70·7	76·7	−0·4	72·7	82	5·7	9·22	−0·57	17	6·3	49
Apia, Samoa ..	1009·5	+0·4	89	71	87·0	73·5	80·3	+0·6	77·4	75	5·3	4·08	−6·30	18	7·5	59
Kingston, Jamaica ..	1012·5	+0·1	90	66	87·5	72·6	80·1	+0·8	74·1	77	4·0	3·02	−0·01	8	7·8	69
Grenada, W. Indies																
Toronto	1010·9	−6·4	62	5	42·6	31·9	37·3	+0·3	32·7	82	7·7	2·03	−0·60	11	2·5	26
Winnipeg	1011·8	−5·6	60	−5	36·7	24·0	30·3	+9·0	26·8	95	6·3	1·29	+0·22	12	2·9	32
St. John, N.B. ..	1010·5	−4·1	54	12	42·2	28·7	35·5	−1·2	32·0	90	6·9	8·21	+3·80	19	2·5	26
Victoria, B.C. ..	1015·7	−0·2	65	34	54·2	41·6	47·9	+3·4	44·8	92	7·0	8·74	+3·33	19	2·5	27

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SHEAR FREQUENCIES IN THE UPPER TROPOSPHERE AND LOWER STRATOSPHERE OVER ENGLAND

By J. K. BANNON, B.A.

In connexion with an investigation of turbulence as affecting aircraft it was necessary to evaluate the frequencies of occurrence over England of various ranges of shear both in the vertical and in the horizontal and also the Richardson number associated with the former. The frequencies of various shears and Richardson numbers occurring just above the tropopause were also investigated. These statistics are presented here, without discussion, in the hope that they may be of use in other connexions. It should be noted that occasions of very strong winds are not properly represented above 20,000 ft. (450 mb. approximately); wind observations are restricted in altitude when winds are strong because of the limited range of the observing radar set.

Shear in the vertical.—Table I(*a*) gives the percentage frequency of occurrence of various ranges of the shear in the vertical, $|\partial \mathbf{V}/\partial z|$, for the 450-mb., 300-mb. and 200-mb. levels ($\mathbf{V}$ is the horizontal wind vector and z is the height measured upwards). The observations made at Larkhill, given to the nearest degree in direction and the nearest knot in speed, were used to compute these shears. One month from each season was examined, *viz.* October 1946, January, April and June 1947; June was chosen in preference to July as there were more observations available for the former month. It is obvious that there is considerable variation in the frequencies from month to month. It is not claimed that any of these months is typical of its particular season.

Table I(*b*) gives the percentage frequencies of various ranges of shears for the upper troposphere (*i.e.* for the 450-mb. level and the 300-mb. and 200-mb. levels when appropriate) and for the lower stratosphere (*i.e.* for the 300-mb. and 200-mb. levels when they were above the tropopause) for the same months as in Table I(*a*).

Richardson number.—Table II(*a*) gives the percentage frequency of occurrence of various ranges of $\log_{10}$(Richardson number) for the same observations for Larkhill from which Table I was derived. The Richardson number* is defined as

$$R_i = \frac{g}{T} \frac{\left(\frac{\partial T}{\partial z} + \Gamma\right)}{\left(\frac{\partial \mathbf{V}}{\partial z}\right)^2}$$

where T=temperature (absolute) and Γ=adiabatic lapse rate of temperature with height. As R_i ranged from very small values to over 1,000, $\log_{10} R_i$ was used in the analysis.

Table II(*b*) gives similar frequencies for the upper troposphere (450 mb. and above) and lower stratosphere (200 mb. and below).

TABLE I—PERCENTAGE FREQUENCY OF OCCURRENCE OF VARIOUS RANGES OF $|\partial \mathbf{V}/\partial z|$ AT LARKHILL

	Shear (kt./1,000 ft.)							No. of obs.	Mean shear
	0–2	2–4	4–6	6–8	8–10	10–12	12–14		
	percentage frequency								kt./ 1,000 ft.
	(*a*)								
200-mb. level									
October 1946	53·8	31·1	12·3	2·8	..	..	..	106	2·36
January 1947	47·0	28·9	12·1	6·0	4·8	..	1·2	83	2·91
April 1947	61·8	26·4	8·8	1·5	..	1·5	..	68	2·11
June 1947	51·7	24·2	18·4	5·7	..	..	..	87	2·53
Total 4 Seasons	53·1	27·9	13·1	4·1	1·2	0·3	0·3	344	2·48
300-mb. level									
October 1946	65·8	26·3	6·1	1·8	..	..	..	114	1·83
January 1947	52·5	35·6	6·9	4·0	1·0	..	..	101	2·26
April 1947	57·0	30·2	12·8	..	..	..	..	86	2·06
June 1947	62·5	32·7	4·8	..	..	..	..	104	1·73
Total 4 Seasons	59·8	31·1	7·4	1·5	0·2	..	..	405	1·96
450-mb. level									
October 1946	63·6	29·7	4·2	2·5	..	..	..	118	1·92
January 1947	45·0	35·9	8·3	6·7	3·3	0·8	..	120	2·76
April 1947	58·5	33·1	4·7	2·8	0·9	..	..	106	2·11
June 1947	59·7	33·3	6·1	..	0·9	..	..	114	1·91
Total 4 Seasons	56·7	33·0	5·9	3·1	1·3	0·2	..	458	2·18
	(*b*)								
Stratosphere (200-mb. level and below)									
October 1946	51·5	29·4	14·7	4·4	..	..	..	68	2·53
January 1947	46·4	29·6	9·9	7·1	5·6	..	1·4	71	3·03
April 1947	59·6	28·6	7·2	2·3	..	2·3	..	42	2·31
June 1947	50·0	22·0	20·0	8·0	..	..	..	50	2·79
Total 4 Seasons	51·1	27·8	13·0	5·6	1·7	0·4	0·4	231	2·73
Troposphere (450-mb. level and above)									
October 1946	64·4	28·4	5·3	1·9	..	..	..	264	1·86
January 1947	49·1	34·5	8·2	5·5	2·3	0·4	..	220	2·51
April 1947	59·4	30·2	8·5	1·4	0·5	..	..	212	2·03
June 1947	60·7	31·7	6·8	0·4	0·4	..	..	249	1·85
Total 4 Seasons	58·8	31·1	7·1	2·2	0·7	0·1	..	945	2·05

Shear and Richardson number at or just above the tropopause.—Wind observations at Larkhill for the month of February 1948 were re-plotted in the neighbourhood of the tropopause, and the winds computed over 1-min. intervals instead of 3-min. intervals as is the normal practice. From these re-computed winds it was possible to derive more accurate wind gradients than from the observations made at standard levels several thousand feet apart. Shears at two levels were investigated, (i) the shear between the wind during the minute in which the tropopause was reached and the wind in the following

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*RICHARDSON, L. F.; The supply of energy from and to atmospheric eddies. *Proc. roy. Soc., London*, A, **97**, 1920, p. 354.

minute; and (ii) the shear between the winds observed in the first and second complete minutes of observations, respectively, within the stratosphere. (i) gives an estimate of the shear immediately above the tropopause or partly across it; (ii) gives the shear just above the tropopause in a layer about 1,200 ft. above the layer considered in (i).

TABLE II—PERCENTAGE FREQUENCY OF OCCURRENCE OF VARIOUS RANGES OF $\log_{10} R_i$; LARKHILL

	$\log_{10} Ri$										
	−1·0 to −0·5	−0·5 to 0·0	0·0 to 0·5	0·5 to 1·0	1·0 to 1·5	1·5 to 2·0	2·0 to 2·5	2·5 to 3·0	3·0 and above	No. of obs.	Mean $\log_{10} Ri$
	percentage frequency										
	(*a*)										
200-mb. level											
October 1946	..	..	3·0	18·0	32·0	32·0	10·0	4·0	1·0	100	1·41
January 1947	..	1·3	7·9	18·4	32·9	22·4	10·5	6·6	..	76	1·38
April 1947	..	..	8·2	14·8	26·2	26·2	16·4	6·6	1·6	61	1·53
June 1947	..	..	10·7	26·2	21·5	22·6	10·7	8·3	..	84	1·32
Total 4 Seasons	..	0·3	7·2	19·6	28·3	26·2	11·5	6·2	0·6	321	1·40
300-mb. level											
October 1946	..	..	12·4	23·0	32·7	22·1	6·2	2·7	0·9	113	1·23
January 1947	1·1	2·1	9·7	28·1	25·8	22·6	3·2	2·1	4·3	93	1·22
April 1947	..	..	18·8	24·7	24·7	20·0	5·9	2·4	3·5	85	1·22
June 1947	..	2·0	10·8	29·4	20·5	14·7	19·6	2·0	1·0	102	1·26
Total 4 Seasons	0·3	1·0	12·7	26·5	26·2	19·8	8·9	2·3	2·3	393	1·24
450-mb. level											
October 1946	0·8	2·5	11·0	26·3	32·3	17·0	6·8	1·7	1·6	118	1·18
January 1947	0·8	4·2	18·3	25·8	29·2	17·5	2·5	1·7	..	120	1·00
April 1947	..	0·9	9·4	35·9	29·2	12·3	8·5	3·8	..	106	1·19
June 1947	..	2·6	6·1	29·9	27·2	22·8	7·9	2·6	0·9	114	1·26
Total 4 Seasons	0·4	2·6	11·4	29·3	29·5	17·5	6·3	2·4	0·6	458	1·11
	(*b*)										
Stratosphere (200-mb. level and below)											
October 1946	..	..	1·5	19·4	28·3	34·3	9·0	6·0	1·5	67	1·42
January 1947	..	1·4	8·3	18·1	29·2	23·6	12·5	6·9	..	72	1·40
April 1947	..	..	7·3	12·2	24·4	24·4	19·5	9·8	2·4	41	1·64
June 1947	..	..	7·8	27·5	19·6	19·6	13·7	9·8	2·0	51	1·47
Total 4 Seasons	..	0·4	6·1	19·4	26·0	26·0	13·0	7·8	1·3	231	1·46
Troposphere (450-mb. level and above)											
October 1946	0·4	1·1	11·0	23·5	33·3	20·4	7·2	1·9	1·2	264	1·23
January 1947	0·9	3·2	14·3	27·2	29·0	19·4	2·3	1·8	1·9	217	1·09
April 1947	..	0·5	13·3	29·8	27·5	17·1	7·6	2·8	1·4	211	1·21
June 1947	..	2·0	9·2	28·9	24·1	20·1	12·5	2·8	0·4	249	1·24
Total 4 Seasons	0·3	1·7	11·8	27·2	28·6	19·4	7·6	2·3	1·1	941	1·20

TABLE III—PERCENTAGE FREQUENCY OF VARIOUS RANGES OF $|\partial\mathbf{V}/\partial z|$ IN THE LOWER STRATOSPHERE AND NEAR THE TROPOPAUSE; LARKHILL

Level	Shear (kt./1,000 ft.)								No. of obs.	Mean shear
	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16		
	percentage frequency									kt./1,000 ft.
(i) Just above or at tropopause*	15·1	48·8	20·9	9·3	2·3	3·5	..	..	86	3·81
(ii) Lower stratosphere*	28·2	43·5	10·6	7·1	7·1	1·2	1·2	1·2	85	3·65
(iii) At 300-mb. and 200-mb. levels†	50·0	32·7	9·2	4·9	2·7	..	0·5	..	184	2·55

* February 1948 † January 1947

Table III gives the percentage frequencies of occurrence of various ranges of $|\partial\mathbf{V}/\partial z|$ for cases (i) and (ii) respectively; for comparison, similar frequencies for the 300-mb. and 200-mb. levels together for the month of January 1947 are given in the same table. The months January 1947 and February 1948 both had periods of disturbed and anticyclonic weather and were thus not dissimilar.

TABLE IV—PERCENTAGE FREQUENCY OF OCCURRENCE OF VARIOUS RANGES OF $\log_{10} R_i$ IN THE LOWER STRATOSPHERE AND NEAR THE TROPOPAUSE; LARKHILL

Level	Log₁₀ *Ri* −1·0 to −0·5	−0·5 to 0·0	0·0 to 0·5	0·5 to 1·0	1·0 to 1·5	1·5 to 2·0	2·0 to 2·5	2·5 to 3·0	3·0 and above	No. of obs.	Mean log₁₀*Ri*
	percentage frequency										
(i) Just above or at tropopause*	..	..	9·3	24·4	39·5	20·9	4·7	1·2	..	86	1·19
(ii) Lower stratosphere*	..	2·4	11·8	18·8	30·6	24·7	5·9	3·5	2·4	85	1·30
(iii) At 300-mb. and 200-mb. levels†	0·6	1·8	8·9	24·2	29·0	22·5	6·5	4·1	2·4	169	1·29

*February 1948; †January 1947

TABLE V—PERCENTAGE FREQUENCY OF OCCURRENCE OF VARIOUS RANGES OF HORIZONTAL SHEAR OVER THE MIDLANDS (REGARDLESS OF SIGN)

	Horizontal shear (hr.⁻¹) 0·00 to 0·05	0·05 to 0·10	0·10 to 0·15	0·15 to 0·20	0·20 to 0·25	0·25 to 0·30	0·30 to 0·35	0·35 to 0·40	0·40 and above	No. of obs.	Mean shear
	percentage frequency										hr.⁻¹
					(*a*)						
200-mb. level										49	0·088
October 1946	51·1	24·5	6·1	6·1	2·0	6·1	4·1	..	..	46	0·071
January 1947	60·9	15·2	8·7	4·3	..	6·5	2·2	2·2	..	38	0·065
April 1947	47·3	29·0	15·8	5·3	..	..	2·6	..	..	33	0·074
June 1947	48·4	27·3	12·1	6·1	..	..	..	6·1	..		
										166	0·075
Total 4 Seasons	52·5	23·5	10·2	5·4	1·2	3·6	2·4	1·2	..		
300-mb. level										68	0·081
October 1946	33·8	32·4	17·6	8·8	4·4	1·5	..	..	1·5	77	0·087
January 1947	31·2	40·2	15·6	6·5	2·6	..	..	..	3·9	60	0·073
April 1947	51·6	21·6	16·7	3·3	1·7	1·7	1·7	..	1·7	56	0·092
June 1947	26·7	37·5	17·9	12·5	..	1·8	1·8	1·8	..		
										261	0·083
Total 4 Seasons	35·7	33·3	16·9	7·7	2·3	1·1	0·7	..	1·9		
450-mb. level										84	0·071
October 1946	52·4	19·0	11·9	7·1	3·6	..	2·4	2·4	1·2	93	0·072
January 1947	40·9	34·4	12·9	6·4	3·2	1·1	..	..	1·1	89	0·087
April 1947	37·1	30·4	15·7	5·6	3·4	4·5	1·1	2·2	..	75	0·063
June 1947	41·3	36·0	16·0	6·7	..	..	..	..	..		
										341	0·074
Total 4 Seasons	42·8	29·9	14·1	6·4	2·6	1·5	0·9	1·2	0·6		
					(*b*)						
Stratosphere (200-mb. level and below)											
October 1946	69·3	19·2	3·8	..	..	7·7	..	..	..		
January 1947	58·0	22·0	10·0	2·0	..	4·0	2·0	2·0	..	26	0·050
April 1947	61·3	22·6	16·1	..	..	..	..	..	..	50	0·065
June 1947	50·0	12·5	12·5	16·6	4·2	..	..	4·2	..	31	0·048
										24	0·089
Total 4 Seasons	59·5	19·8	10·7	3·8	0·8	3·1	0·8	1·5	..		
										131	0·063
Troposphere (450-mb. level and above)											
October 1946	42·4	25·7	13·7	8·6	4·0	1·1	2·3	1·1	1·1	175	0·080
January 1947	36·8	35·5	13·9	7·2	3·0	1·2	..	..	2·4	166	0·081
April 1947	40·4	28·2	16·0	5·8	2·6	3·2	1·9	1·3	0·6	156	0·083
June 1947	35·8	38·6	16·4	7·1	..	0·7	0·7	0·7	..	140	0·072
Total 4 Seasons	39·0	31·7	14·9	7·2	2·5	1·5	1·3	0·8	1·1	637	0·079

Table IV gives similar frequencies of $\log_{10} R_i$ for the layers (i) and (ii) and also for the 300-mb. and 200-mb. levels together. It will be noted that the character of all three frequencies is similar.

Horizontal shear.—The shear in the horizontal may be defined as

$$\partial \mathbf{V}/\partial n - \mathbf{V}/r$$

where n is the horizontal direction at right angles to $\mathbf{V}$ and to its right, and r is the radius of curvature (positive for cyclonic motion) of the stream-line.

Table V(*a*) gives the percentage frequencies of occurrence of various ranges of the horizontal shear (regardless of sign) over the Midlands for the months October 1946, January, April and June 1947, for the 450-mb., 300-mb. and 200-mb. levels. The wind observations at Larkhill, Downham Market and Liverpool were used for this computation. Owing to the difficulty of estimating the curvature of the stream-lines no great accuracy can be claimed for a particular observation of horizontal shear; however, taken all together, the observations probably give a good idea of the true frequency distribution.

Table V(*b*) presents similar frequencies for the upper troposphere (450 mb. and above) and lower stratosphere (200 mb. and below). As in the frequencies given in Tables I and II there is considerable variation between the several months which may or may not illustrate the true seasonal variation.

SEA BREEZE ACROSS LONDON

By W. A. L. MARSHALL

A very good example of what appears to have been a sea breeze spreading across London to Hampshire and Berkshire from the Thames Estuary occurred on July 1, 1949.

During the early afternoon the wind recorded by an anemometer on the roof of the Meteorological Office, Kingsway, had been NE. 6 kt., with fluctuations of speed and direction typical of a quiet summer day. The wind veered to E. at 1550 G.M.T., increased quickly to double its former strength at 1605 G.M.T., and continued as a fresh breeze with gusts of 20–23 kt. throughout the evening. Temperature fell sharply with the onset of the sea breeze and relative humidity rose by 17 per cent.

The resulting cool interlude in an existing warm spell was the subject of much comment in London. Values of the " cooling power "* of the air based on Kingsway readings of wind speed and temperature give only an incomplete indication of human reactions in the suburbs. Nevertheless, Table I serves as a convenient method of comparing the coolness of July 1 with the warmth of the previous evening. The 2nd and 3rd columns are broadly applicable to a person in summer clothes relaxing in the garden, while the 4th and 5th columns have their lesson for the very energetic who wish to avoid chills after their exertion. The marked drop in cooling power of the air between 1800, and 2100 on June 30 was due to the wind falling off from 6 m.p.h. to calm.

TABLE I—COOLING POWER OF THE AIR OVER CENTRAL LONDON FOR SURFACES AT A TEMPERATURE OF 98°F.

Time	For a dry surface		For a wet surface	
	June 30	July 1	June 30	July 1
G.M.T.	*millicalories per square centimetre per second*			
1500	12 (pleasant)	15 (pleasant)	49	53
1800	10 (warm)	27 (cool)	45	69
2100	4 (very warm)	29 (cool)	<20	69

The time of occurrence of sudden changes of wind, temperature and relative humidity at meteorological observing stations in the Thames Valley on July 1, 1949, and the amount of change in the following hour, is summarised in Table II.

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*GOLD, E.; The effect of wind, temperature, humidity and sunshine on the loss of heat of a body at temperature 98°F. *Quart. J. R. met. Soc., London,* **61**, 1935, p. 316.

TABLE II—CHANGES OF WIND, TEMPERATURE AND RELATIVE HUMIDITY, JULY 1, 1949

Place	Time of change	Wind					Temperature		Relative Humidity	
		Before onset		After onset		Highest gust	Before onset	Change	Before onset	Change
	G.M.T.	°true	kt.	°true	kt.	kt.	°F.	°F.	%	%
Shoeburyness	1130	080	1	130	7	8	64	−1	56	+ 9
West Malling	(1530)	060	7	060	14	*	75	−5	46	+14
Biggin Hill	(1550)	030	2	060	10	*	76	−7	40	+22
Kingsway	1605	030	6	090	12	23	76	−4	46	+17
Croydon	1610	030	4	060	10	18	78	−5	38	+22
Kew Observatory	1640	050	6	100	15	22	77	−5	37	+21
Hendon	(1650)	050	6	100	8	*	77	−5	35	+24
Northolt	1725	040	10	100	13	*	77	−6	36	+21
London Airport	1730	030	6	080	15	20	79	−8	34	+20
S. Farnborough	1810	070	3	120	9	20	77	−8	40	+28
Benson	(1950)	(360)	6	(060)	10	*	..	..	..	..
Abingdon	2040	060	4	100	8	16	..	..	..	..

Entries in brackets are approximate.
* = No self-recording anemograph.

Wind, temperature and relative-humidity changes shown in the tracings of autographic records in Fig. 1 indicate that the sea breeze moved across London and thence to South Farnborough at the mean speed of the easterly wind. The difference in wind turbulence before and after its onset is noteworthy. It then seems to have flowed through the gap between the Chilterns and the White Horse Hills to the north-west of Reading, reaching Abingdon with sufficient vigour to overcome a local NE. wind of appreciable strength which had been noted as having occurred there fairly regularly each evening during the fine spell.

The main sea breeze, which reached West Malling through the Medway Valley at 1530 G.M.T., was preceded by similar though less pronounced weather changes about two hours earlier. These may have been caused by a minor sea breeze from the Chatham area.

Smoke from London caused an abrupt temporary deterioration of visibility to 3–4 miles at Northolt and London Airport with the onset of the easterly wind. The sky, which had previously been clear apart from small amounts of fine-weather cumulus, became about three-quarters covered with strato-cumulus clouds for a time.

The normal diurnal changes of temperature and relative humidity had been in progress for some hours before the sea breeze reached Benson and Abingdon. No significant change in the rate of temperature fall was obvious but the hygrograms show that relative humidity, which had been rising steadily at both places, fell temporarily at Benson and remained steady for an hour or so at Abingdon at the estimated times of arrival of the sea breeze.

Isochrones of the onset of the sea breeze are given in Fig. 2. The temperature lapse rate over south-east England on the afternoon of July 1 was superadiabatic from the surface to 3,750 ft. An anticyclone moved eastward across England during the day. The consequent veering of a light geostrophic wind from NE.

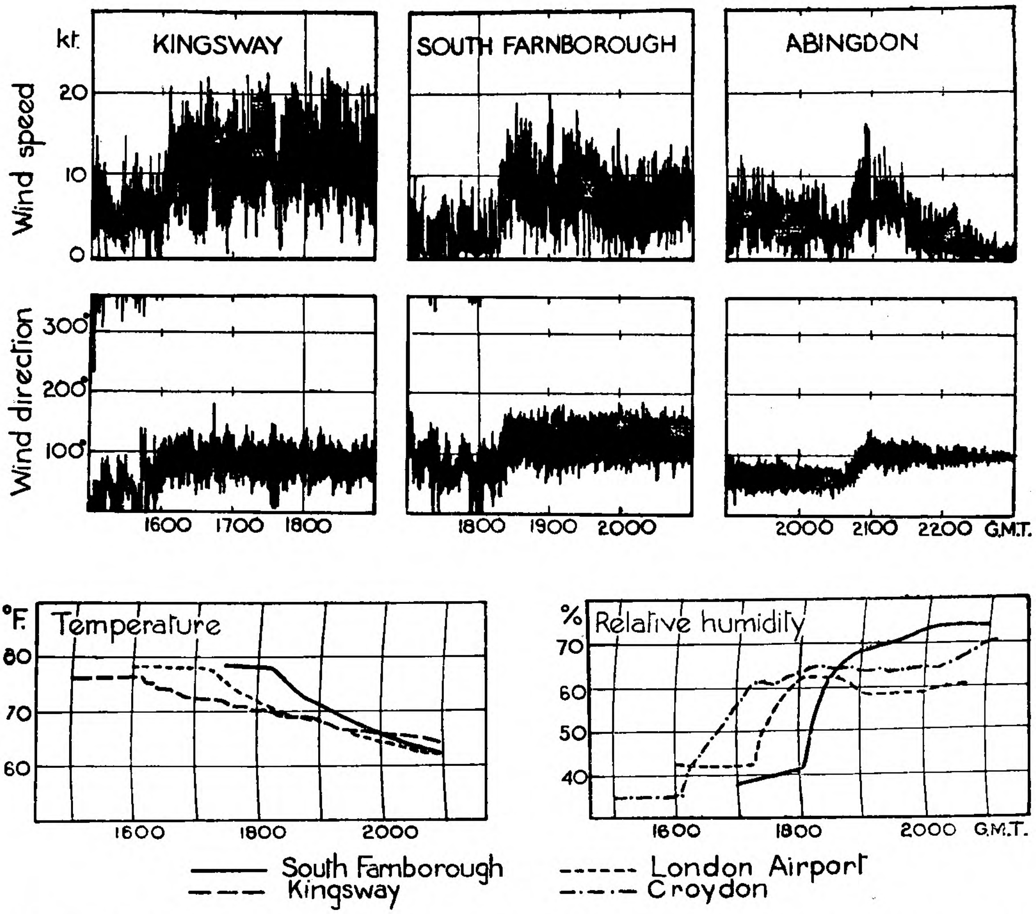

FIG. I—AUTOGRAPHIC RECORDS OF WIND, TEMPERATURE AND HUMIDITY, JULY 1, 1949

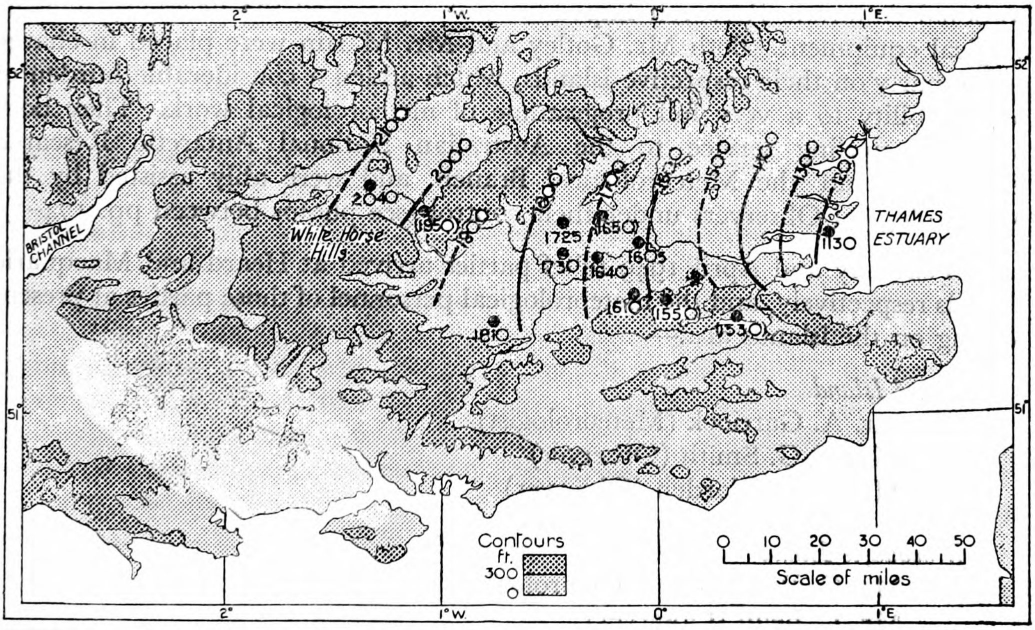
2°
1°W.
0°
1°E.
52°
51°
BRISTOL CHANNEL
White Horse Hills
THAMES ESTUARY
2100
2040
2000
(1950)
1900
1800
1725
1730
1810
1700
(1650)
1640
1605
1600
(1610)
1500
(1550)
(1530)
1400
1300
1200
1130
Contours
Ft.
300
0
0 10 20 30 40 50
Scale of miles

FIG. 2—ISOCHRONES OF ONSET OF SEA BREEZE, JULY 1, 1949

All times are G.M.T. Times in brackets are approximate to ENE. probably contributed to the penetration of the sea breeze 100 miles inland. Upper winds were as follows:—

Height	Downham Market						Larkhill					
	0900		1500		2100		0900		1500		2100	
	°true	kt.	°true	kt.	°true	kt.	°true	kt.	°true	kt.	°true	kt.
Surface	360	8	030	10	080	8	360	15	349	12	230	3
1000 mb.	360	8	030	10	085	15						
900 mb.	340	7	022	7	079	10	356	13	009	10	065	10
700 mb.	334	4	359	3	011	4	327	11	006	5	103	10

METEOROLOGY AT HEARD AND MACQUARIE ISLANDS

By W. J. GIBBS

Meteorological Branch, Department of Interior, Australia

The Australian National Antarctic Research Expedition established stations at Heard Island in December 1947 and at Macquarie Island in April 1948. Included in the members of the two parties were the following meteorological personnel:—

Heard Island

Mr. A. V. Gotley (Meteorologist)
Mr. A. T. Carroll (Observer)
Mr. K. W. York (Observer)

Macquarie Island

Mr. A. Martin (Meteorologist)
Mr. R. Chadder (Observer)
Mr. B. Monkhouse (Observer)

These men are all members of the Meteorological Branch, Department of Interior, which, in addition to making available their services to the Australian National Antarctic Research Expedition, also provided the necessary meteorological equipment. Both Mr. Gotley and Mr. Martin were placed in charge of the party on their respective islands, which added a considerable burden of responsibility to a very full programme of meteorological work. They both rendered sterling service to the Australian National Antarctic Research Expedition and the Meteorological Branch, and were ably assisted by the Meteorological Observers under their control (see photos between pp. 174–5).

In February and April 1949 relief parties arrived at Heard and Macquarie Islands respectively, and the meteorological personnel of those parties at present serving on the islands are:—

Heard Island

Mr. A. Garriock (Meteorologist)
Mr. R. G. Smith (Observer)
Mr. O. E. Warden (Observer)

Macquarie Island

Mr. N. Robertson (Meteorologist)
Mr. L. Behn (Observer)
Mr. W. Denham (Observer)

Continuity of observations was maintained during the " change over " and the present parties are maintaining the high standard set by the pioneer teams.

Geography.—The geographical co-ordinates and heights of the islands are:—

Heard Island—53°01'S., 73°23'E., 16 ft. above M.S.L.
Macquarie Island—54°30'S., 158°57'E., 20 ft. above M.S.L.

Heard Island is thus approximately 2,000 nautical miles and Macquarie Island 800 nautical miles from the nearest point on the Australian coastline.

Heard Island is roughly circular in shape and about 15 miles across. The terrain rises sharply from the coastline to a central dome at about 8,000 ft. in the centre of which a volcanic peak, Big Ben, rises to a height of 9,000 ft. Snow completely covers the island in winter but in summer the snow-line rises to about 500 ft.

Macquarie Island is about 18 miles in length and from 2 to 5 miles wide. Most of the island consists of a plateau about 1,000 ft. in height. In midwinter snow lies permanently on the plateau and occasionally covers the lower ground, but in the summer no part of the island is permanently snow covered.

Establishment.—Before the meteorological and other scientific activities of the parties could commence, it was necessary to erect living quarters and install scientific apparatus and radio equipment. This entailed the unloading of the expedition ship and the erection of camps sufficiently robust to withstand the winds of gale force which blow on these islands. Equipment for routine meteorological observations, both of conditions at the surface and in the upper air, had to be installed so as to work in rigorous conditions which were unfamiliar to the personnel operating it. In addition to their routine meteorological tasks the meteorologists shared in the work of building and maintaining the camp sites.

Observations.—At three-hourly intervals observations are made of pressure, dry- and wet-bulb temperature, surface wind speed and direction, and weather and cloud conditions. Once daily a radio-sonde ascent provides pressure, temperature and humidity data to a height of about 55,000 ft. When cloud conditions are suitable, pilot-balloon observations of upper winds are made four times daily. The results of these observations are transmitted with the minimum delay possible by radio to Australia where they are circulated to certain offices of the Meteorological Branch and included in the regular meteorological W/T broadcasts of Australian data.

Results.—There are two main results which are forthcoming from these observations. The first is the accumulation of meteorological data for the two islands. Observations were made at Macquarie Island during the years 1911–14 but only fragmentary data were available previously for Heard Island. When published, this data will be a significant contribution to the mass of observational material available for meteorological research. The second result is the appreciation of the usefulness of the reports in the analysis of the structure of the atmosphere in the Australian region and their contribution to the problem of forecasting in that region.

Since the receipt of the first radio reports from Heard and Macquarie Islands in Australia, efforts have been made to co-ordinate them with the results of observations made in Australia. More experience will be necessary before final conclusions will be possible, but it is the firm impression of meteorologists engaged in using the reports that a general picture of the air circulation over the ocean to the south of Australia is possible. The work of the late Sir Edward Kidson*† on the meteorology of the Southern Ocean, together with the meteorological results of earlier Antarctic expeditions, provides a useful basis for the present investigations, but the study of meteorology has made such rapid strides during the past ten years that most of the current work is of a more advanced nature than the former investigations.

Synoptic analyses of the data are carried out at Heard and Macquarie Islands, in the Analysis and Development Section, Central Meteorological Bureau, and by Deputy Directors in the States. There has been considerable correspondence between the Deputy Directors and Central Meteorological Bureau on the subject, in addition to which articles on synoptic analysis by Langford and Gibbs have appeared in the *Weather Development and Research Bulletin.* At present a comprehensive report on the first year's operation of the meteorological stations at Heard and Macquarie Islands is being prepared and it is hoped that this, together with the data and analysed charts will be published as soon as possible after completion.

Tentative conclusions after a year's experience in analysing the data may be summarised as follows:—

Using all available reports, it is possible to locate fairly accurately the major pressure systems over the Southern Ocean; the great depressions of the Southern Ocean appear to follow two main tracks, the first from Marion Island to Heard Island and thence towards the east or south-east, the second from the southern coastline of Australia to the vicinity of Macquarie Island and then mainly to the south-east. The great depressions of the Southern Ocean have a definite influence on pressure patterns and, therefore, weather over Australia. This means that Southern Ocean analysis is of assistance in short-period forecasting in Australia and may greatly assist the preparation of extended period forecasts.

RADAR WEATHER ECHOES

By R. F. JONES, B.A.

Part III

Occlusion by Radar.—As may, perhaps, be expected, the radar picture of the occlusion shows some of the features of both warm and cold fronts which have already been described.

The picture of the occlusion, as seen on the P.P.I., suggests that quite frequently the structure is as simple as the charts suggest with a single belt of precipitation often visible to ranges of 40 miles or more (see photograph (*a*) of series of photographs between pp. 174–5). The rain belt is wider than that accompanying a cold front but less extensive than that associated with an active warm front. The surface position of the front is usually clearly marked by the termination of the echo at a well defined edge. Unlike the cold-front echo, however, this well defined edge only rarely gives signs of isolated cores of high intensity, and the impression given is that although the up currents are larger at this edge than in the normal warm front they are nevertheless wide-spread and fairly uniform in strength, *i.e.* cumulonimbus development is much less frequent in the straightforward occlusion than in the cold front.

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*KIDSON, E.; Discussion of observations at Adélie Land, Queen Mary Land and Maquarie Island. Australasian Antarctic Expedition 1911–14. Scientific Reports, Series B, Vol. VI Meteorology. Sydney, 1946.

†KIDSON, E.; Daily weather charts extending from Australia and New Zealand to the Antarctic Continent. Australasian Antarctic Expedition 1911–14. Scientific Reports, Series B, Vol. VII Meteorology. Sydney, 1947.

Occasionally the structure indicated is considerably more complex than in the case outlined above with a much more extensive area of precipitation and the appearance of more or less parallel lines of higher echo intensity (and hence almost certainly higher rainfall intensity) within the general echo, and also, on some occasions, signs of isolated cores of echo suggesting cumulonimbus activity (see photograph (*b*)).

Radar on such occasions can give a much finer picture of the precipitation associated with the front than can possibly be obtained from even detailed weather charts, and may therefore be of considerable assistance in determining the detailed structure of the front. This possibility is further demonstrated on those occasions when the warm sector has already become so narrow that it is impossible to distinguish on the charts the warm front from the cold front, with the result that the front is drawn as already occluded. Such an occasion is shown in photograph (*c*).

In the vertical cross-section the type of echo is usually more akin to that from the warm front than from the cold front in that a bright band is usually visible about the height of the freezing level (photographs (*d*) and (*e*)), although occasionally it may be interrupted by the appearance of a stronger column of echo. The echo is often more intense than the warm-front type, and it is noteworthy that more extensive echoes from above the bright band than for the warm front are usually to be seen which, although retaining their characteristic diffuse appearance, may exhibit some variations in intensity (photograph (*e*)). This greater vertical extent of the echo indicates that either the ice crystals are growing to a greater size above the freezing level in the occlusion than in the warm front or that aggregation of the ice crystals to form snow-flakes takes place at a greater height (or lower temperature). This has been interpreted* as an indication that the wide-spread vertical currents are stronger in the case of the occlusion than for the warm front, while the variations in intensity of the echo above the bright band indicate a somewhat less uniform value of these up currents. The up currents are, however, still relatively small compared with the isolated vertical currents which lead to cumulonimbus formation and the occurrence of clearly defined columns of weather echo. Such columns of echo do occur occasionally in the occlusion echo but with less frequency than in the cold-front cases.

In general it can be said that the radar evidence indicates that, while warm and cold fronts conform quite closely to the accepted ideas of the processes which produce the frontal rain, the occlusion processes are sometimes considerably more complex and not capable of being interpreted by a simple model of the frontal structure.

Further details of the photographic illustrations follow below :—

Photograph (*a*).—This P.P.I. photograph was taken at 1345 G.M.T. on September 10, 1948. The radial markers are at 20° intervals from magnetic north and the range circles are at 5-mile intervals, the outermost circle being at a range of 55 miles. The channels through the echo on approximate bearings of 30° and 50° are caused by local screening of the radio energy by trees. The

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*JONES, R. F.; The heights and temperatures at the tops of radar echoes associated with various cloud systems. *Met. Res. Pap., London,* No. 458, 1949.

surface position of the front, *i.e.* the edge of the echo nearest to the station, is fairly well defined but without any clearly marked cores of higher intensity while the rain belt is seen to be wider than in the normal cold front.

Photograph (*b*).—This P.P.I. photograph was taken at 1511 G.M.T. on August 6, 1948. The precipitation pattern is clearly of a more complex nature than in photograph (*a*) with a tendency to bands of precipitation without clear-cut edges, but in the north-west and north stronger and more isolated echoes of higher intensity appear, indicating, it is thought, cumulonimbus development.

Photograph (*c*).—This photograph was taken at 1203 G.M.T. on December 13, 1948. Range and bearing markers are not shown on the photograph but the outer edge of the photograph corresponds to a range of about 65 miles while magnetic north is indicated by the bright radial line. It will be noted that from an area just north of the station the echo divides into two arms, one running south-south-east and the other south-south-west from this area. It is thought that the echo to the south-south-east and east of the station is from the warm front while that to the south-south-west, which is somewhat narrower, comes from the cold front. The complex echo to the north is associated with the occlusion. A narrow warm sector of this character is unlikely to be indicated clearly on synoptic charts.

Photograph (*d*).—This H.R.T. photograph was taken at 1337 G.M.T. on September 10, 1948, on a bearing of 76° magnetic and is therefore a cross-section at right angles to the front shown in photograph (*a*). As in photograph (*a*) the surface position of the front (nearest to the station) shows a clearly defined edge but without any evidence of column structure. The bright-band effect is to be seen at a height of 10,000 ft. but it is noteworthy that the echo extends with a diffuse character to a considerable height above the bright band. The effect of increase with height of the wind is clearly visible in the inclination of the edge of the echo above the bright band to the vertical. The effect is more marked above the bright band due to the lower terminal velocity of the snowflakes or ice crystals compared with that of the raindrops beneath the bright band.

Photograph (*e*).—This H.R.T. photograph was taken at 1129 G.M.T. on December 13, 1948, on a bearing of 349° magnetic and is therefore a vertical section on this bearing of the P.P.I. echo shown in photograph (*c*), at the time when the eastern arm of the echo was over the station. The broad bright band centred at about 6,000 ft. and extending 72 miles is clearly visible while the extensive echoes above the bright band show variations in intensity although still of a diffuse character without clear-cut edges and tops.

(*To be concluded*)

OFFICIAL PUBLICATIONS

A paper by Mr. T. H. Kirk, B.Sc., on the seasonal change of surface temperature of the North Atlantic Ocean has been approved for printing as a *Geophysical Memoir.*

Mr. Kirk has made a harmonic analysis of the seasonal change of surface temperature of the North Atlantic Ocean. The parameters of the harmonic series are presented in the paper on charts, and it is shown how they can be readily used to obtain a formula for the seasonal change at any point within the area covered. Mr. Kirk also discusses the relative importance of the various factors affecting the seasonal change and provides a series of charts showing the rate of change of mean sea-surface temperature for each month of the year.

The following publication has recently been issued:—

PROFESSIONAL NOTES

No. 101—The climates of Addu Atoll, Agalega Islands and Tristan da Cunha. By E. V. Newnham, B.Sc.

This note summarises two or three years' observations on two tropical islands in the Indian Ocean and one in the South Atlantic.

On Addu Atoll (lat. 1°S.), the southernmost of the Maldive Islands, the predominant wind in January was northerly, but backed month by month through W. to between S. and SE. in July, veering gradually back to N. in later months. Rainfall averaged about 7 in. per month, without clear indication of wet and dry seasons, and monthly mean temperature ranged between 81°F. and 83°F.

On one of the Agalega Islands (lat. 11°S.) winds were observed to be variable in January and February, while the SE. trade wind prevailed in other months. Rainfall was very similar to that on Addu Atoll, but mean temperature was 82°F. from February to April and 78°F. in August and September.

Tristan da Cunha (lat. 11°S.), although not far south of the anticyclonic belt of the southern hemisphere, was found to experience winds and weather more appropriate to the " roaring forties " than to an anticyclone during most of the year. Observations on ships show that W. to NW. gales are frequent in this neighbourhood, especially in the southern winter, when Beaufort force 7 or more is reached on 10 to 14 days per month. The central mountain of Tristan causes local distortion of these winds, and made SW. the most frequent direction. Mean temperature was 52°F. in August and September, and nearly 65°F. in February. Rainfall averaged about 5 in. per month.

ROYAL METEOROLOGICAL SOCIETY

As most readers will know six symposia were held at Oxford during the last week in March as part of the Society's Centenary celebrations. We are publishing brief reports, three of which are given in this number, on these symposia.

March 29, 1950: The physics of clouds and precipitation. Chairman—Professor G. M. B. Dobson.

Dr. Dobson in his introductory remarks reviewed for a crowded audience recent laboratory work on the physics of clouds and precipitation with particular reference to the temperatures at which water-drops usually freeze and also to the properties of the various ice-forming nuclei which can initiate the direct deposition of ice from vapour in supersaturated conditions.

In the animated discussion which followed, in which it was pleasing to listen to such a strong representation from France, the results of much original work were made public for the first time.

M. Bricard and *Prof. Dessens* described their methods of obtaining water-drops for study. *M. Lafargue* reported that he had found that droplets of various solutions of radius less than 20 microns invariably froze at a temperature of

$-40 \pm 1{\cdot}5$°C., and that as the radius of the drops was increased the critical temperature of freezing rose to approach asymptotically a value dependent on the nature and concentration of the solution. The value of the absolute threshold temperature was suggestively similar to the temperature of -41°C. recently put forward in a number of quarters as that below which condensation never occurred; Dr. Schaefer (United States) whose name will always be associated with the artificial seeding of clouds (" Project Cirrus ") had, however, obtained for this temperature the value of $-38{\cdot}9$°C.

Mr. Mason described recent advances in the theory of crystal growth. Dendritic growth was due to local variations in the degree of supersaturation, but the growth of a crystal face where the degree of supersaturation was small and nearly constant over the face could not be explained in this way. F. C. Frank of Bristol[1]* had presented to the Faraday Conference of 1949 a theory of crystal growth based on the theory of " dislocations ", from which Mr. Mason had obtained results in the case of ice which seemed consistent with experience, *e.g.* a prism took 5 minutes to attain a length of 35 microns at a temperature of -35°C. He thought that dendritic growth was confined to relatively high temperatures.

No discussion of the physics of clouds and precipitation would be complete without reference to the electrical aspect. *M. Queney*, in the unavoidable absence of Prof. Pauthenier, read a paper by the latter on the importance of electrified particles in the clearing of artificial fogs, each sweeping a path ten times its own diameter, and *Prof. Gill*, a non-meteorologist, described an experiment in which the separation of electrostatic charge on the bombardment of an ice target by water-drops was such that the target was always left negative and the drops positive. The implications of this result he left to the meteorologists.

Prof. Dobson had been anxious that as the results of so much laboratory work would be reported the study of clouds themselves would not be neglected. The balance was redressed by *Dr. Schaefer* and *Dr. Frith*, both of whom showed numerous photographs. Then *Mr. Palmer* and *Mr. Brewer* discussed splintering. *Mr. Brewer* was of the opinion that there were not enough natural nuclei to account for all the ice particles present in the atmosphere, and that in the physics of clouds splintering was thus of fundamental importance.

In the late evening *Dr. Schaefer* delighted another large audience with a "slow motion " re-showing of his photographs, and with great goodwill answered a long series of searching questions by Mr. Gold and others on his latest work in New Mexico.

There was general regret that time did not permit the subject to be further explored. It would appear that meteorologists would now do well to pause and reflect on the great body of material which has so recently been made available—little attention has, for example, been paid in this country to Russian work on atmospheric electricity[2]—and to consult with physical chemists and crystallographers on the basic problems of crystal formation[3].

Meanwhile the publication of the papers read will be awaited with impatience.

*REFERENCES

1. MOTT, N. F.; Theory of crystal growth.† *Nature, London*, **165**, 1950, p. 295.
2. FRENKEL, J.; Atmospheric electricity and lightning. *J. Franklin Inst., Philadelphia Pa.*, **243**, 1947, p. 287.
3. RIDDAL, E. K.; How crystals grow. *Nature, London*, **164**, 1949, p. 303.

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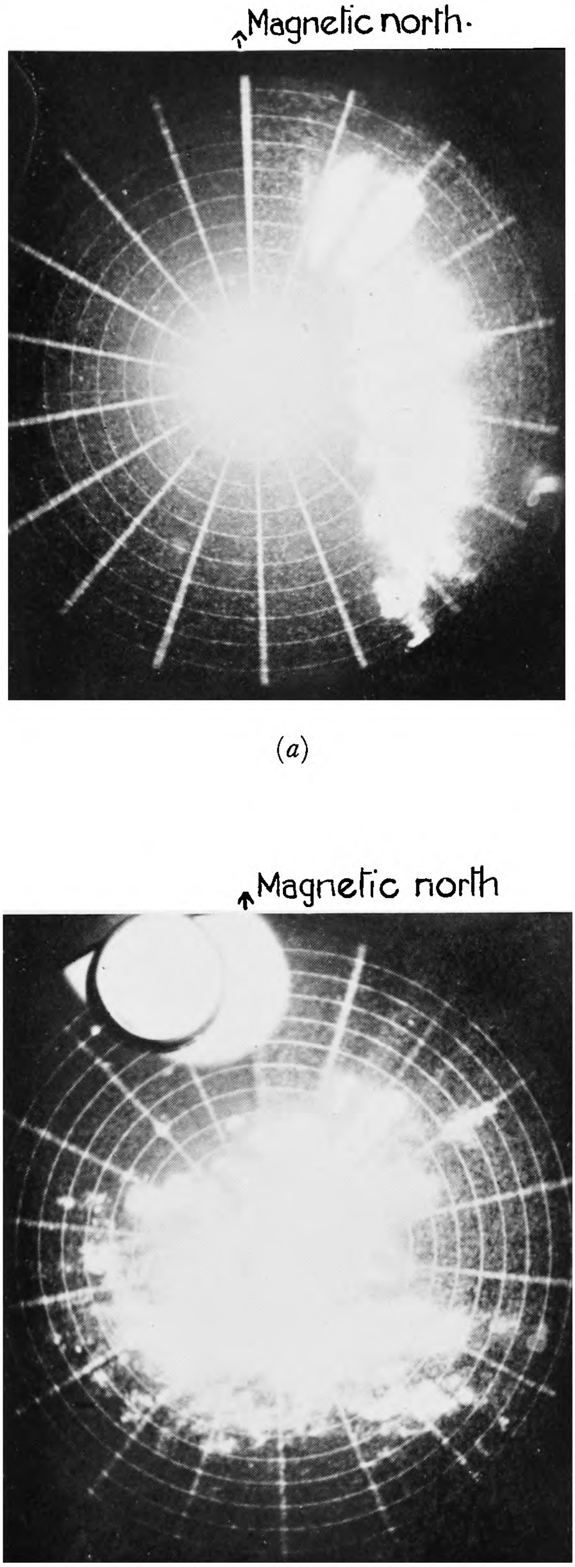
†This gives the latest position of the Bristol School.

[*To face p.* 174

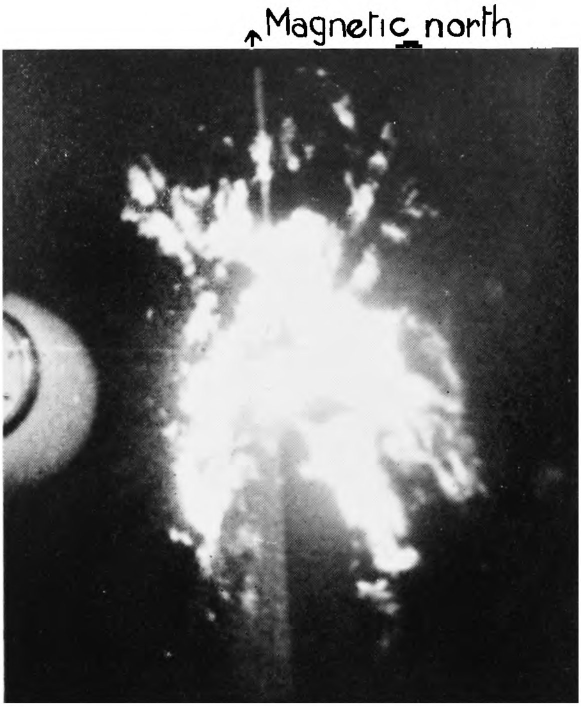

Magnetic north.
Magnetic north

(*a*)

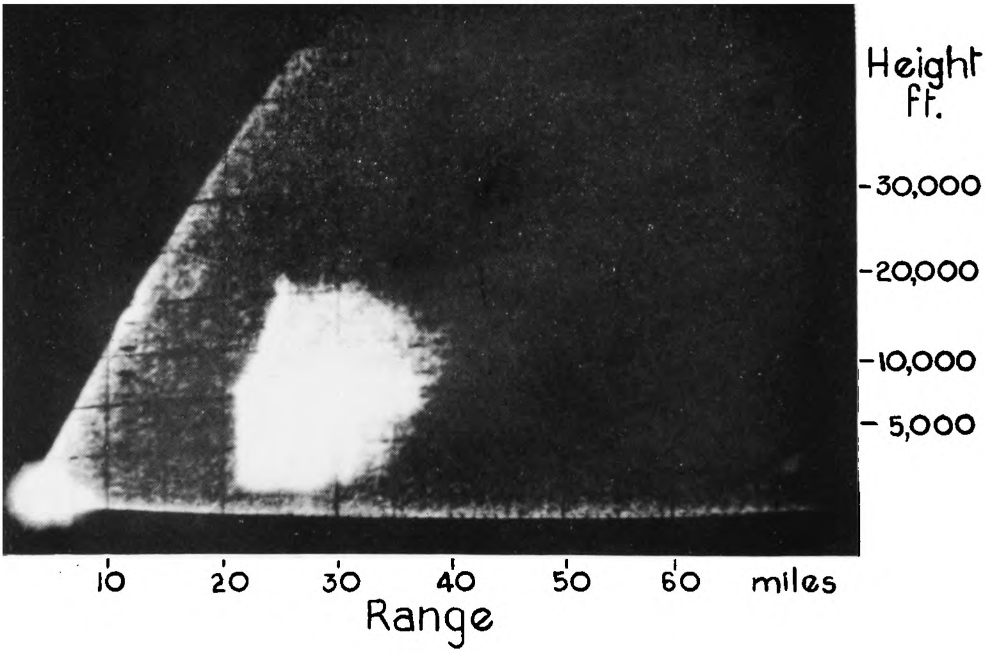
(*b*)

OCCLUSION BY RADAR

(see p. 170)


Magnetic north

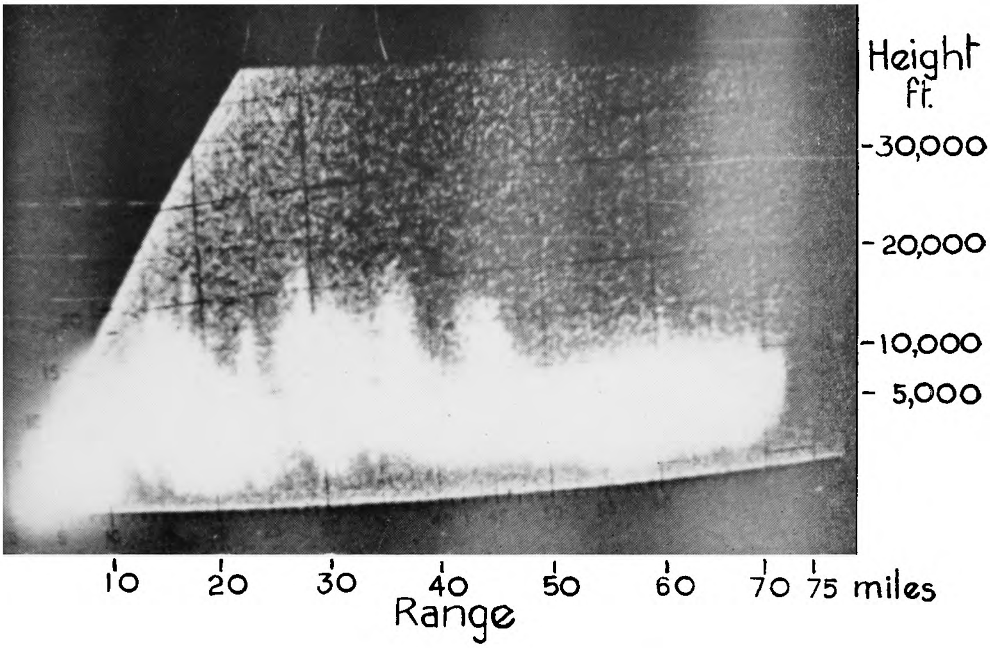
(*c*)


Height
ft.
-30,000
-20,000
-10,000
- 5,000
10
20
30
40
50
60
miles
Range

(*d*)

OCCLUSION BY RADAR

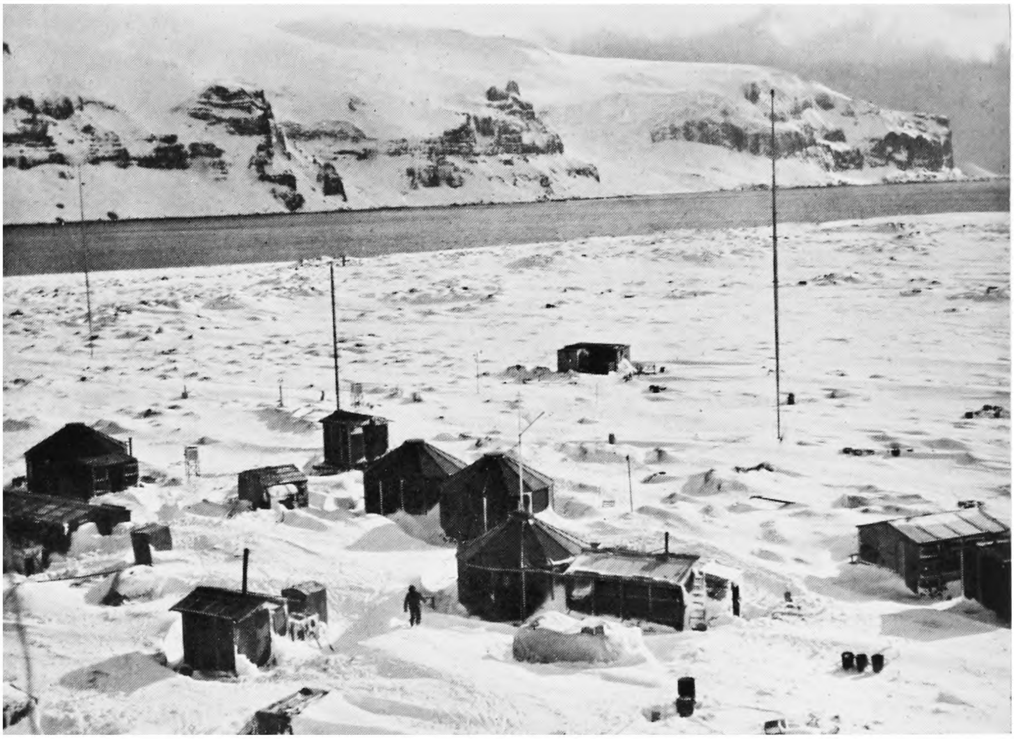
(see p. 170)



(*e*)
OCCLUSION BY RADAR
(see p. 170)

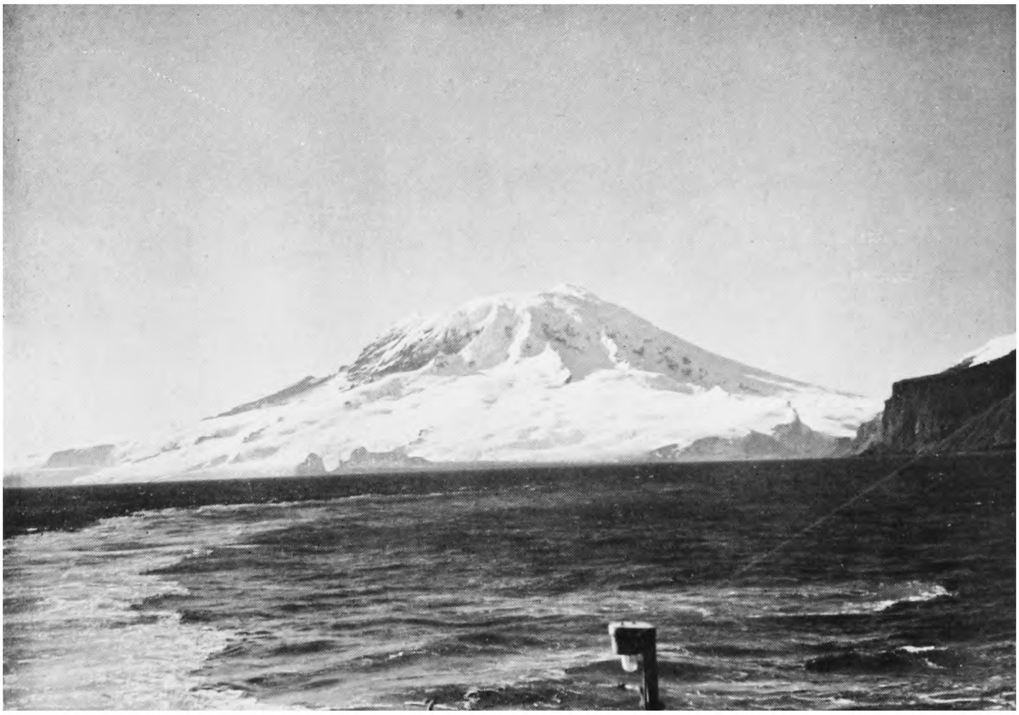
By courtesy of the Department of Information, Government of Australia

A. V. GOTLEY, CHIEF METEOROLOGIST AND OFFICER IN CHARGE, HEARD ISLAND, 1948
(see p. 168)



By courtesy of the Department of Information, Government of Australia

GENERAL VIEW OF CAMP AT HEARD ISLAND



By courtesy of the Department of Information, Government of Australia

CENTRAL DOME AT HEARD ISLAND

(see p. 168)

March 30, 1950: The general circulation of the atmosphere. Chairman—Mr. E. Gold.

Dr. C. G. Rossby opened the discussion after the preliminary remarks by the Chairman. He stressed the fact that, although thermal insolation is the fuel upon which the atmospheric engine feeds, for short-time forecasts we may look to the dynamical rather than the thermodynamical aspects of the problem; this view would be held suspect by Dr. Bleeker. The attempt to solve the dynamical problem consists in the construction of simple models to account for the main observed phenomena, and the gradual adjustment of these models towards complexity to account for further new information. These models would be, for example, independent of local topography and then the model adapted to account for what is observed in topographically significant areas. The choice of the fundamental assumption lies, roughly speaking, between assuming either the constancy of angular momentum or of vorticity referred to axes fixed at the earth's centre (sometimes this is referred to as absolute vorticity and the vorticity relative to the rotating earth as relative vorticity; the terminology seems unfortunate). Dr. Rossby pointed out that neither assumption seems to hold exactly and that some compromise is necessary. As an example he showed the distribution of vorticity through a region containing a jet stream; there was a maximum to the north of the jet stream, while to the south there was a rapid falling off to a small constant value. An examination of the regions of the earth in which either assumption would hold almost exclusively would be of great value. Dr. Rossby also showed some figures of experiments made by heating a rotating fluid and following the motion by means of a light powder.

Dr. S. Petterssen attacked the problem by considering whether it is possible to have a tendency towards both radiative and dynamic equilibrium, and showed that, for such equilibrium, vorticity relative to the rotating earth must increase with height in northern latitudes and decrease with height near the equator. By discussing a general vorticity theorem and applying it to polar regions, he inferred the existence of a belt of low pressure around a polar continent; this is applicable to the south-polar region but not near the north pole owing to the topography, which would cause lows over the North Pacific and North Atlantic Oceans and possibly over the Mediterranean. On applying the theorem to equatorial regions the local structure, such as the doldrums, was inferred. In middle latitudes, with neither heat sources nor sinks, the application of the theorem is more difficult but indicates a general drift northward of cyclones and southward of anticyclones over a long period of time. Dr. Petterssen showed some very interesting statistical distributions of cyclonic and anticyclonic patterns for a 40-year period which agreed with his general deductions from the vorticity theorem.

Dr. E. T. Eady considered the circulations necessary in order to account for the heat balance in the atmosphere assuming a source of heat at low levels near the equator and a sink at high levels near the pole. The simplest circulation, upflow at the equator balanced by downflow at the pole is inadmissible, and it is necessary to have dynamically unstable patterns in order to account for the flux of heat toward polar regions. These unstable patterns bear some relation to the atmospheric structures found in middle latitudes.

Dr. J. Van Mieghem dealt with the total heat balance in a thermodynamic sense, and showed that the customary neglect of certain terms, in particular those due to condensation and lateral stresses, leads to zonal circulations in which there is a transport of heat toward the equator. Some of the common assumptions must be re-examined.

Dr. A. H. R. Goldie showed what the general circulation of the atmosphere really looks like with the aid of vertical cross-sections up to a height of 40 Km. Some of the information was obtained from calculations made on explosion sound waves. The circulations appear to be made up of cellular patterns one above the other, and Dr. Goldie pointed out that V. Bjerknes had inferred such circulations in the solar envelope but had not considered the application to the atmospheric envelope.

The discussion took place in the evening. Interesting slides were contributed by *Cdr. Rex* (United States) of " blocking " over the British Isles and by *Mr. Dwyer* (Australia) of a north-south cross-section near the east coast of Australia (prepared by Loewe) showing a strong jet stream notably nearer to the equator than those in the northern hemisphere. *Dr. Sutcliffe* remarked that a picture in which there was a single heat source and sink is a serious oversimplification. Other speakers included *Dr. Nyberg* (Sweden) and *Capt. Bundgaard* (United States).

March 30, 1950: Climatic change. Chairman—Professor Gordon Manley.

During the symposium on " Climatic change " on the afternoon of March 30, a wide range of topics was covered, from the ice ages to changes of weather in the last few years. *Prof. K. Faegri* of Norway sounded a cautionary note when he spoke of the difficulties of interpreting in terms of climate the evidence of past vegetation. The northward extension of the occurrence of a plant might mean warmer winters or warmer summers, or be the effect of some other weather element. Climatic fluctuations did not affect all areas similarly and there was a serious lag in the response of vegetation type to climate.

Prof. H. C. Willett of the Massachusetts Institute of Technology turned to more recent periods, and illustrated the temperature changes of the last hundred years from the records of a world-wide network of stations. The Arctic had warmed rapidly and the lower latitudes more slowly since about 1885. This amelioration extended southward to about latitude 40°S. The Antarctic on the other hand was getting colder. The effect was greatest in winter temperatures, and might be associated with the intensification of the continental anticyclones and their extension to the north-west. The absence of continents in the southern hemisphere accounted for the difference there.

Dr. Lysgaard of Denmark presented some data broadly confirming Prof. Willett's remarks.

Mr. C. D. Ovey of the Natural History Museum, London, returned to the study of the distant past by means of small shells taken from the sea bed. Analysis of a sample from the tropical Atlantic showed how the deeper layers contained an increasing proportion of shells of creatures which thrived in cooler water—these deposits might have been laid down in the last ice age.

Other contributors to the discussion included *Dr. Wallén* of Sweden who described changes in Swedish glaciers; *Miss N. Carruthers*, who stressed on behalf of Dr. C. E. P. Brooks the importance of the uplifting of mountains as a cause of ice ages, and *Mr. H. H. Lamb*, who drew attention to the different response of southern and northern hemispheres to increased heating of the equatorial belt. Periodicities and solar variations also received mention.

Mr. D. J. Schove presented some estimates of past climate in China and Japan based on historical records, and pointed out that the pressure and temperature rise of the last 50 years had moved slowly southward over the northern hemisphere.

Prof. G. Manley added some comments on the probable oceanic circulation during an ice age, and concluded with a plea for a search for early instrumental records which would add to our knowledge of the weather of the eighteenth century.

LETTER TO THE EDITOR

Altocumulus castellatus at Farnborough

The photograph in the centre section of the December 1949 issue of the *Meteorological Magazine* with the caption "Altocumulus castellatus at Farnborough 0840, July 13, 1945 " prompts some comments which have often been in my mind. Explanations of the word "castellatus" suggest small development and small clouds as is seen by reference to standard publications such as " Cloud Forms " or " Meteorological Observer's Handbook ". This idea is borne out by the famous photographs by G. A. Clarke given in these books, though measurement suggests that each example shows development through some 3,000 ft.

The picture under consideration shows an isolated cloud with a thickness of at least 5,000 ft. and a horizontal extent of at least two miles. The general characteristics of this cloud are much nearer to "cumulus" than to "altocumulus castellatus " and the fact that its base is outside the normal range associated with the term " cumulus " should surely not prevent us from using the more appropriate name. Again, codes are the servant of the observer, not his master. It would surely be more realistic and convey more information to code this as cumulus with a base in the medium range.

This type of situation is not rare. A similar one was observed at Kew at midday on November 22, 1949. There was considerable development from well above the normal convection level. To one cloud there was a mammatus base, estimated at about 8,000 ft. which persisted for some ten minutes only. Another cloud, presumably with a convection base around the same level had, from the point of view of visibility, a very much lower base and was giving light rain at the ground. These clouds must have had vertical development of the order of 10,000 ft. Add to this some low and medium layer cloud and one has a situation which is a real challenge to the observer's ingenuity.

R. H. ELDRIDGE

Kew Observatory, Richmond, Surrey, December 31, 1949

NOTES AND NEWS

" Science of Weather " Exhibition

The exhibition " The Science of Weather ", presented at the Science Museum to mark the Centenary of the Royal Meteorological Society, was opened on March 27 by the Rt. Hon. Herbert Morrison, M.P., Lord President of the Council.

The Rt. Hon. G. Tomlinson, M.P., Minister of Education, took the chair and spoke of his own early interest in forecasting the weather prospects for Saturday afternoon cricket.

Sir Robert Watson-Watt, F.R.S., gave the Society's appreciation of the action of the Ministry of Education and Science Museum in arranging the exhibition. Referring to the relations between radio and meteorology, Sir Robert pointed out that, while radio was of immense value to the forecaster for the collection of observations, yet on the other hand it increased his difficulties by providing an audience of millions over a very large area for his forecasts.

Mr. H. Morrison congratulated the Society on its Centenary and spoke of the value of the exhibition in assisting the public to grasp what scientists are doing and thinking. He remarked that the aspect of meteorology in which most people were concerned was weather forecasting, and he said he would like to pay tribute to the work of the Meteorological Office whose services were relied upon by so many professions from airmen to film producers. Forecasters, he pointed out, have to publish their forecasts daily to millions, and could not, like many other scientists, keep their conclusions within a professional circle which would not let the reputation of the particular science suffer. Actually, he said, the standard of success is higher than many people think, as a recent test showed forecasts of rain in the London area were correct 9 times out of 10. The exhibition, he went on, dealt not only with forecasting but with other applications of meteorological knowledge, from bridge design to the comfort of houses, and with research. Finally, in declaring the exhibition open, he congratulated all those who had contributed to its production.

The exhibition, which will remain open until June 27, presents a unique and most comprehensive survey of meteorological methods and applications. There are five main sections:—

(*a*) historical;

(*b*) techniques of observing the weather with instruments ranging from visibility meters to " Sferic " apparatus;

(*c*) forecasting the weather, with many synoptic charts, including the historic D-day ones, and a mechanical plotting model;

(*d*) weather in our daily lives which covers applications from water supply to bridge design; and

(*e*) research, in which real " cloud seeding " on a small scale may be seen and current research charts examined.

The contributors of exhibits include the Meteorological Office, Royal Meteorological Society, the National Physical Laboratory, Building Research Station, University Meteorological Departments and several publishers and scientific instrument makers.

Hailstones encountered by aircraft near Lake Victoria, east Africa

Mr. Grinsted, Acting Director, British East African Meteorological Department, has sent a report on hail encountered by a Viking aircraft 40 miles south of Kisumu on the afternoon of April 26, 1949.

The aircraft entered a cloud described by the pilot as " murky and vaguely cumulonimbus " and encountered hail large enough to crack the ½ to ¾ in. thick clear-vision panel and severely dent the leading edges. The aircraft was in the hail for only about 3 sec. and was afterwards in very heavy rain which penetrated the setting of the clear-vision panel and poured into the cabin. No turbulence was encountered. On arrival at Entebbe the size of the hailstones was estimated from the dents at 2–2½ in. diameter.

Mr. Grinsted states that hail is not often reported in east Africa, but that the region of the hills to the north-east of Lake Victoria is one from which hail is most frequently reported.

New Indian Geophysical Series

The Meteorological Department of India has instituted a new quarterly periodical, the *Indian Journal of Meteorology and Geophysics.* The first number, for January 1950, was received in the Meteorological Office Library in March.

The *Memoirs* series which contains the most important of the papers produced by the Department will continue to be published, but the *Scientific Notes* and *Technical Notes* have been discontinued.

The first number of the Journal, which opens with a message from the Prime Minister of India, has 86 pages of scientific material. The longer articles are by Dr. S. K. Banerji on the foreshadowing of Indian rainfall, and by D. N. Wadia on geophysical methods in mineral exploration. There are five short articles, notes and news, reviews and letters to the editor.

Monthly climatological table for the British Commonwealth

The publication of the " Monthly climatological table for the British Commonwealth " will cease with the completion of the 1949 tables on pp. 186-7 of this issue.

It has been felt for some time that the reasons which led to the original demand for the table over 75 years ago were no longer valid, and the lack of response to the note which appeared on p. 237 of this Magazine in August 1949 confirmed this opinion.

The British Commonwealth Table has quite a long history. It originated in a request, made to G. J. Symons in 1873 by the Editor of a paper known as *The Colonies*, for the preparation of a monthly table of weather data for publication. The data were collected from the Directors of the various services, and publication began in 1874 with a table for 16 stations spread over the five continents.

Publication in *The Colonies* ceased in June 1881, but Symons, impressed with the value of the information, decided to continue its publication in his own *Symons's Meteorological Magazine.* The first tables, those for July and August 1881, appeared there in March 1882. In 1920 *Symons's Meteorological Magazine* was taken over by the Meteorological Office, and publication of the table continued without interruption. It was suspended during World War II, but was resumed with the table for January 1947 which appeared in the Magazine for July of that year.

One of the chief reasons for ceasing publication of the table now is that monthly means of pressure, temperature and rainfall for all parts of the world are available regularly in the CLIMAT messages broadcast on the 5th–7th of the months following those to which the data refer. These broadcasts, in so far as they are received at the Central Forecasting Office, Dunstable, are tabulated regularly in the Branch of the Office which deals with World Climatology. A more complete issue in manifolded typescript is made by the United States Weather Bureau, Washington, D.C., in a series entitled *Monthly Climatic Data for the World.* These issues are available for consultation in the Meteorological Office Library at Harrow. They cover some 550 stations in both northern and southern hemispheres.

Letters advising them of the cessation of the table were sent to all services contributing data, but the Director would like to take this opportunity of expressing his thanks again to all those who have forwarded their information with such unfailing regularity in the past or who have contributed in any way towards the preparation of the table.

REVIEW

The climate of the Netherlands. Temperature, precipitation and wind. By A. Labrijn. Koninklijk Nederlandsch Meteorologisch Instituut No. 102. Mededeelingen en Verhandelingen, Serie A, No. 53. 8vo, 9½ in. × 6¾ in., pp. 78. *Illus.* 's Gravenhage, 1948. 2·50 florins. Dutch with English summary.

Dr. Labrijn's work " The Climate of the Netherlands during the last two and a half centuries ", published in 1945, is well known as a mine of information for students of recent climatic variations.

In this publication, which is a supplement to the earlier one, he gives them more information in the shape of data for about a century ending in 1947 of temperature and precipitation for Utrecht, Flushing, Maastricht and Groningen (precipitation only) and frequencies of wind for Utrecht. The temperature data have been corrected and may be considered homogenous.

G. A. BULL

OBITUARIES

Hugh Robert Mill, D.Sc., LL.D.—Many of the readers of this Magazine will have learnt of the passing of Hugh Robert Mill on April 5, at the age of 88, with a sense of personal loss. From 1901 until 1919 he was Editor, maintaining publication even during the difficult war years of 1914–18. Although failing eyesight compelled him to retire in 1919 he continued unimpaired mentally. As recently as March 30 he wrote himself to the Rainfall Section of the Meteorological Office " you have given me a delightful picture of your show (of April 1) at Harrow ". A rainfall observer has paid this tribute : " I well remember the first personal letter Dr. Mill sent me, in his own handwriting, some thirty-five years ago. I always treasured that letter because it gave the measure of encouragement, which is always so very valuable at certain periods in one's life."

Dr. Mill had a full life, devoted mainly to the study of water in nature, dealing successively with oceanography, the study of lakes, the flow of rivers, the Antarctic and especially rainfall. At the University of Edinburgh he specialised in chemistry and physics, becoming chemist and physicist in 1884 to the Scottish Marine Station newly established by Mr. John Murray of the *Challenger*, at Granton on the Firth of Forth. There, in addition to marine research, he carried on a regular second order meteorological station under the supervision of Alexander Buchan and a series of experimental observations with Dr. Aitken's various patterns of thermometer screens. This work renewed his interest in geography, and he was appointed lecturer in physiography in the Heriot Watt

College, Edinburgh, where he published in 1891 a standard text-book on physical geography, appropriately entitled " The realm of nature ".

In 1892 Mill was appointed Librarian to the Royal Geographical Society, where his work included the preparation of subject and author catalogues of geographical literature and the first systematic mapping of the depths of English Lakes (published in 1895).

Following the death of G. J. Symons, F.R.S., in 1900, Mill became Director of the British Rainfall Organization and Editor of *British Rainfall* and *Symons's Meteorological Magazine* until he retired in 1919, when the Organization was incorporated in the Meteorological Office. During this period he applied his authoritative geographical knowledge, and his experience, to open up new lines of research in the study of rainfall over the British Isles. In addition to reports included in *British Rainfall* and *Symons's Meteorological Magazine* he contributed to the *Geological Survey Memoirs* chapters on the rainfall of various counties and set out the results of some of his researches in other papers, including the following:—

On the distribution of mean and extreme annual rainfall over the British Isles. *Min. Proc. Instn. Civ. Engrs., London,* **155**, Part I, 1904, p. 1.

Map studies of rainfall. *Quart. J. R. met. Soc., London,* **34**, 1908, p. 65.

Report on the rainfall in the Exe valley. *Geogr. J., London,* **34**, 1909, p. 630.

Unprecedented rainfall in East Anglia, August 25–26, 1912. *Quart. J. R. met. Soc., London,* **39**, 1913, p. 1.

Isomeric rainfall maps of the British Isles (in collaboration with Carle Salter). *Quart J. R. met. Soc., London,* **41**, 1915, p. 1.

In his enforced retirement Mill prepared " The Record of the Royal Geographical Society, 1830–1930 " on the occasion of the Society's Centenary and retained his life long interest in Antarctic exploration. In 1892 he assisted the Society in equipping for scientific work the sailing ships *Balaena* and *Active*, which set out from Dundee to explore the possibilities of whaling in the Antarctic, and in 1905 wrote " The Siege of the South Pole ". In 1923 he published " The Life of Sir Ernest Shakleton ".

Mill was Honorary Secretary of the Royal Meteorological Society from 1902 to 1906 and President in 1907 and 1908, vice-President of the Royal Geographical Society 1927–31, and President of the Geographical Association 1932. Amongst the honours and awards bestowed on him the following may be mentioned :—

1894—Makdougal Brisbane Medal of the Royal Society, Edinburgh;

1915—Victoria Research Medal of the Royal Geographical Society;

1918—Symons Memorial Medal of the Royal Meteorological Society;

1923—Gold Medal of the Royal Scottish Geographical Society;

1930—Cullum Medal of the American Geographical Society, New York;

1932—Commander Norwegian Order of St. Olav; and

1950—the newly instituted Hugh Robert Mill Medal and Prize of the Royal Meteorological Society for research in rainfall of the British Isles.

The originality of his Christmas greetings was a recurring source of pleasure to his many friends, and the last, quoted below, seems particularly appropriate as illustrating his undimmed mentality and his philosophy throughout life.

" This is the fiftieth and belike the last
Up-raising signal on our Yule-tide mast
To hail the shifting feet of friends afloat
And dip in memory of the friends who passed.

. . . .

The Sun that lavished largesse when on high
Now lurks impoverished low in Winter's sky
Withdrawn but to prepare a better Spring
And vault to Summer's height as June goes by."

Dr. Mill married first in 1889, Frances, daughter of Dr. F. B. MacDonald, Inveraray, who died in 1929, and in 1937 he married Alfreda, daughter of Frederick Dransfield, Darton, Yorkshire, and in his writings gratefully acknowledged their constant assistance.

J. GLASSPOOLE

W. J. Humphreys.—We regret to report the death of the well known American meteorologist, Professor W. J. Humphreys on November 10, 1949, at the age of 87 years. Professor Humphreys is best known to British meteorologists for his theory of the radiative equilibrium of the stratosphere, published in 1909 independently of and almost simultaneously with E. Gold's work, and for his famous book " Physics of the Air ". He was distinguished in physics and astronomy as well as meteorology.

METEOROLOGICAL OFFICE NEWS

Meteorological Office, Harrow.—As part of the centenary celebrations of the Royal Meteorological Society, the Director and Lady Johnson received some 250 Fellows, including the President Sir Robert Watson-Watt, F.R.S., their guests, and overseas delegates, at the Meteorological Office, Harrow, on the afternoon of April 1, 1950.

All branches at Harrow gave exhibitions of their work and the Forecast Division showed a working forecast office and " sferics " apparatus.

During the afternoon a radio-sonde balloon was released from the roof in a somewhat boisterous wind. Some cine-photographs taken by the British Broadcasting Corporation were later broadcast on the television newsreel.

Radio-sondes are now the most important source of upper air information. There are many different types of instrument in use in different countries, and it is known that the readings are subject to errors. This can give rise to systematic discontinuities at national frontiers on the synoptic charts. Something is known about the source of these errors, but hitherto we have had no experimental data to determine their relative magnitude for different types of instruments. Thus the results of a series of comparisons of types of radio-sonde instruments in use within the European Region made recently at Payerne in Switzerland will be of special interest. These trials were organised by Dr. J. Lugeon, Director of the Swiss Meteorological Service. The British representatives at the trials were Dr. D. N. Harrison and Mr. H. E. Painter. A practically complete British radio-sonde station was taken to Payerne.

Meteorological colloquia at Dunstable.—A feature of the activities at the Central Forecasting Office is the occasional colloquium held in the Napier Shaw Laboratory. The fifth colloquium, recently held, was opened by Mr. H. H. Lamb who took as his subject " Long spells of weather in the British Isles during the past half-century ". Previous subjects have been:—

Warm-front waves and warm-occlusion secondaries.

Cyclonic development and the importance of vertical stability in the process.

Secondary depressions on cold occlusions.

Growth and decay of convection cloud.

Frost warnings.—By arrangement with the Ministry of Agriculture and Fisheries an improved system of spring frost warnings was introduced in April. These warnings give fruit-growers and market-gardeners the expected value of the night minimum air temperature on sites classified as " below average ", " average " and " above average " for their immunity from frost, depending on orographic features. The warnings are telephoned in the early afternoon from selected provincial meteorological offices to County Branch Offices of the National Farmers' Union, by whom they are disseminated to the growers.

R.A.F.V.R. Meteorological Section.—Mr. J. L. Galloway, Fighter Command, is Chief Meteorological Officer of the Section, with the rank of Squadron Leader (V.R.) He is assisted by Miss P. F. Parker (Sgt. V.R.).

Arrangements for non-continuous training and for " summer camps " for 1950 are well in hand. For a fortunate few it is possible that, if negotiations being undertaken at the time of going to press are successful, this may mean a journey to B.A.F.O. Other popular choices of areas for training are London, Cornwall, Northern Ireland and Scotland.

There are still vacancies in this Section; any who are interested are invited to apply to the Director, M.O.10.

Ocean weather ships.—A paragraph appeared in the April number about the co-operation between Netherlands' and British ocean weather ships. While on her way to Station J, which she took over for the first time, the Netherlands' O.W.S. *Cumulus* called in at Plymouth and was visited by the Marine Superintendent, Meteorological Office. He was greatly impressed by the ship and the ship's company. On the arrival of the Netherlands' ship on station J, Captain A. W. Ford, Master of O.W.S. *Weather Recorder*, accompanied by his Chief Officer, Radio Overseer and Meteorological Officer, paid her a courtesy visit.

Under the auspices of the British Ship Adoption Society three of the British ocean weather Ships have been " adopted " by schools at Glasgow.

(i) *Weather Observer* by Hillhead High School.

(ii) *Weather Recorder* by Whitehill Senior Secondary School.

(iii) *Weather Watcher* by Eastbank Senior Secondary School.

By exchange of letters and personal visits the scholars are kept in touch with the work of the ships, and they send magazines and periodicals to the ships' companies. The interest aroused amongst the scholars of Glasgow may result in some recruits for the Meteorological Office.

Sports and social activities.—In the final of the competition for the Air Ministry football cup at Northolt on April 14, the Meteorological Office, holder for the past two years, played the Directorate of Accounts. A hard game, in which defences predominated, resulted in a one-one draw, and the Bishop Shield points were shared.

In the current competition for the Bishop Shield the Office has so far gained 56 points.

The Meteorological Office Social and Sports Committee, which is responsible for general questions affecting the social interests of staff, and for organising the participation of the Office in inter-departmental competitions, has recently been reconstituted, and copies of the new rules have been circulated. An important change is the affiliation to the Committee of the Social and Sports Clubs at Dunstable and Harrow.

The Annual General Meeting of the Harrow Social and Sports Club was held on March 22, 1950, when plans for summer sports and athletics were made.

Ties in Meteorological Office colours (maroon with double narrow diagonal stripe in light blue) are now available. These ties are for sale to all members (and retired members) of the Meteorological Office, at 5*s*. each. Silk squares in the same colours, measuring 36 in. × 36 in. can be obtained at 19*s*. each. Orders, together with the necessary remittance, should be addressed to the Honorary Secretary, Meteorological Office Social and Sports Committee (Mr. H. D. Hoyle), Meteorological Office (M.O.14) Air Ministry, Kingsway, London, W.C.2.

WEATHER OF APRIL 1950

Mean pressure was above 1020 mb. around the Azores and over part of northern Canada and slightly below 1000 mb. off the west coast of Norway. It was about 5 mb. above the average for April north of the Azores. There was a large area with pressure below the average extending from Algeria northwards beyond Spitsbergen and from east Greenland south-eastwards to western Russia and Asia Minor, the deficit exceeding 10 mb. off the west coast of Norway.

In the British Isles the weather of the month was unsettled and wet, with prevailing winds from the south-west and north-west quadrants. In southern and midland districts of England it was very sunny. An unusually severe snowstorm occurred in south-east England on the night of the 25th–26th.

From the 1st–3rd a deep depression moved from the south-west of Iceland to the Baltic; winds were westerly veering to N., strong to a gale locally at exposed stations on the 1st and 2nd; showery weather prevailed, and local thunderstorms occurred on the 2nd. Long periods of bright sunshine were recorded, however, on the 2nd and 3rd. On the 4th another depression was centred off south-west Iceland, and a trough of low pressure crossed the British Isles; on the 5th and 6th a new disturbance in mid Atlantic approached our western seaboard and further troughs passed across the country. Rain or showers occurred on the 4th and scattered showers, chiefly in the west and north, on the 5th and 6th. In the south, conditions on the 6th and 7th were affected by a continental anticyclone and rather warm, fair weather prevailed. From the 7th–9th a depression over mid Atlantic moved east-north-east to the neighbourhood of Thorshavn and then turned north, and on the 10th a secondary depression moved rapidly east across north Ireland and north England. Rain fell in western and northern districts on the 7th and showers occurred generally from the 8th–11th. Gales were recorded locally on the 8th and 9th and were wide-spread and severe in places on the 10th; gusts of 94 m.p.h. and 92 m.p.h. were registered respectively at Liverpool and Squires Gate. Subsequently, in the rear of depressions over the North Sea, a spell of cool north-westerly winds occurred, with showers of rain, hail, sleet and local thunder but long periods of bright sunshine. On the 15th a wedge of high pressure moved south-east across the British Isles and low screen minimum temperatures were registered locally on the mornings of the 15th and 16th (22°F. at Eskdalemuir on the 15th and 23°F. at Eskdalemuir and 26°F. at Elmdon on the 16th). On the 17th a depression off south-west Ireland moved to France; rainfall was general and rather heavy locally in England. On the 19th and 20th another ridge moved south-east over the country followed by a weak trough. Fair weather prevailed in most parts on the 19th but some rain, mostly slight, occurred in the west and north on the 20th. Thereafter the Azores anticyclone spread north-east giving another fair day. The period 19th–22nd was among the warmest spells of the month; day temperatures exceeded 60°F. locally, particularly on the 20th and 21st. On the 22nd a small depression developed off north-west Ireland and moved south-east, giving rain generally on the 22nd and 23rd. Meanwhile, a depression east of Greenland moved south-east to the southern North Sea. In the rear of this disturbance an arctic air stream, with strong gusty winds, covered the British Isles; temperature fell rapidly and sleet and snow showers occurred. By 1800 G.M.T. on the 25th a secondary polar depression was situated over the Bristol Channel, and subsequently it moved along the English Channel, being centred over the Straits of Dover by 0600 G.M.T. on the 26th. Unusually heavy snowfall occurred in south-east England; on the morning of the 26th level snow lay 6 in. deep or more in a narrow belt from Throwley, 4 miles south-west of Faversham in Kent, to Upavon and Everleigh on the Wiltshire Downs. Much damage occurred to trees, shrubs, telegraph poles, etc. Low screen minima included 21°F. at Newton Rigg and 22°F. at Eskdalemuir on the 25th and 25°F. at Elmdon and Wittering on the 26th. On the closing days of the month a trough of low pressure associated with an Atlantic depression moved slowly north-east across the British Isles causing rain generally and a considerable rise in temperature; a maximum of 64°F. was registered at Mildenhall on the 30th.

The general character of the weather is shown by the following provisional figures :—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ..	68	21	+0·1	135	+5	105
Scotland	62	17	−0·7	150	+5	99
Northern Ireland ..	64	25	−0·4	189	+8	80

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, DECEMBER 1949

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
	Mean of day M.S.L.	Diff. from normal	Absolute Max.	Absolute Min.	Mean values Max.	Mean values Min.	Mean values ½ Max. and Min.	Mean values Diff. from normal	Mean values Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1013·2	+0·6	55	30	48·0	39·2	43·6	+2·1	41·3	87	5·5	1·47	−0·82	17	1·6	20
Gibraltar	1018·0	−2·3	70	36	61·9	53·2	57·5	+1·5	53·6	85	5·7	9·36	—	14	3·8	39
Malta	1018·1	+1·9	71	44	63·4	52·8	58·1	+0·2	56·0	72	4·9	0·96	—	10	6·2	64
St. Helena	1013·9	−1·9	72	54	67·7	57·1	62·4	+1·5	57·4	95	7·8	0·74	−1·08	8	—	—
Lungi, Sierra Leone	1010·5	—	90	69	85·9	72·6	79·3	—	74·5	92	3·5	1·06	—	6	7·4	—
Lagos, Nigeria ..	1009·3	−1·2	92	66	90·6	69·7	80·1	−1·7	76·8	91	6·1	0·00	—	0	7·0	60
Kaduna, Nigeria ..	1010·2	—	92	52	88·6	55·5	72·1	−2·2	53·7	14	0·5	0·00	0·00	0	10·4	91
Chileka, Nyasaland	1011·6	−1·0	95	60	85·3	68·4	76·9	+0·8	69·5	73	5·4	6·77	+1·05	15	6·2	48
Lusaka, Rhodesia ..	1010·6	−0·8	88	61	79·8	63·4	71·6	−0·2	65·3	85	6·5	9·07	+2·63	25	5·1	39
Salisbury, Rhodesia	1010·6	−1·2	85	55	78·9	60·7	69·8	+0·4	62·8	72	5·5	5·70	−1·40	15	5·8	44
Cape Town	1013·5	−0·8	88	47	76·7	60·3	68·5	+0·6	58·0	57	2·1	0·42	−0·39	5	—	—
Palmietfontein, S. Africa	1009·9	—	87	47	78·9	56·8	67·9	—	60·5	69	4·0	7·32	—	16	9·0	—
Mauritius	1014·3	+0·6	93	64	88·0	69·8	78·9	+0·6	69·3	60	4·2	1·28	−3·40	16	9·5	71
Calcutta, Alipore Obsy.	1014·3	−1·3	87	49	79·7	53·9	66·8	+0·3	57·8	66	0·3	0·00	−0·24	0	9·3	86
Bombay	1012·3	−1·2	92	63	86·8	67·2	77·0	−0·4	66·6	68	0·2	0·00	−0·05	0	10·3	95
Madras	1013·2	−0·3	85	62	83·6	67·4	75·5	−1·2	69·4	78	3·8	0·04	−5·31	1	9·5	84
Colombo, Ceylon ..	1010·1	−0·2	89	66	85·4	72·0	78·7	−0·8	72·8	85	5·3	3·35	−1·77	6	5·7	49
Singapore	1008·1	−1·6	91	72	86·0	73·7	79·9	0·0	75·4	85	6·2	12·56	+2·00	26	3·8	32
Hongkong	1016·9	−2·8	80	56	69·1	61·7	65·4	+2·4	60·9	78	—	0·40	−0·63	11	3·4	32
Sydney, N.S.W. ..	1010·4	−1·5	98	56	76·8	62·6	69·7	−0·4	63·9	69	5·2	1·84	−1·02	8	7·3	51
Melbourne	1012·2	−0·5	91	46	71·3	52·4	61·9	−2·9	54·3	59	4·8	1·24	−1·03	9	7·2	49
Adelaide	1013·0	−0·3	100	49	79·2	56·5	67·9	−3·2	57·3	43	4·0	0·20	−0·83	4	8·6	60
Perth, W. Australia	1011·6	−1·6	105	56	83·2	61·7	72·5	+1·7	63·8	54	1·0	0·00	−0·56	0	10·3	72
Coolgardie	1010·9	−0·3	109	48	90·4	61·8	76·1	+0·4	59·8	37	2·9	0·51	−0·18	3	—	—
Brisbane	1012·1	+0·1	95	61	83·6	66·5	75·1	−1·3	67·9	68	3·3	3·48	−1·41	4	10·3	75
Hobart, Tasmania	1007·0	−2·7	89	38	65·3	48·6	56·9	−3·3	49·7	52	5·7	1·46	−0·53	13	7·1	46
Wellington, N.Z. ..	1007·5	−4·7	72	44	64·7	52·4	58·5	−0·5	55·3	74	5·8	3·92	+0·70	13	8·1	54
Suva, Fiji	1007·3	−1·3	90	71	84·4	74·2	79·3	+0·3	75·4	86	6·5	15·00	+2·48	24	4·9	37
Apia, Samoa ..	1007·5	−0·4	88	72	85·5	73·4	79·5	−0·5	76·7	81	6·1	26·46	+12·44	26	4·1	32
Kingston, Jamaica	1013·3	−0·7	91	65	86·8	69·5	78·1	+0·4	71·5	80	2·4	1·42	−0·17	6	8·4	76
Grenada, W. Indies																
Toronto	1022·9	+5·3	57	13	37·7	27·0	32·3	+5·2	28·3	78	7·9	3·05	+0·58	14	3·3	37
Winnipeg	1019·8	+1·1	37	−25	10·4	−2·8	3·8	−2·0	2·4	—	5·9	1·61	+0·67	12	3·5	43
St. John, N.B. ..	1021·2	+7·2	52	4	37·0	22·5	29·7	+5·3	27·5	89	6·5	6·33	+2·16	12	3·6	41
Victoria, B.C. ..	1014·2	−2·5	53	18	42·1	31·0	36·5	−4·6	34·3	89	8·1	8·22	+2·48	25	1·7	20

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, YEAR 1949

STATIONS	PRESSURE		TEMPERATURES							RELATIVE HUMIDITY	MEAN CLOUD AMOUNT	PRECIPITATION			BRIGHT SUNSHINE	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1018·2	+3·3	86	23	59·6	45·5	52·5	+2·1	48·2	78	5·5	19·10	−4·70	125	4·9	40
Gibraltar	1018·2	+0·3	99	36	72·3	60·2	66·3	+2·1	61·1	77	4·1	31·53	—	77	7·7	64
Malta	1017·3	+1·9	94	36	71·3	59·0	65·1	−1·0	61·6	68	3·5	20·29	—	86	8·9	74
St. Helena	1016·1	−1·0	82	51	68·2	57·9	63·1	+2·1	58·3	96	7·3	33·06	+1·42	185	—	—
Lungi, Sierra Leone	1012·0	—	94	63	86·1	73·4	79·7	—	74·4	87	5·2	122·13	—	154	—	—
Lagos, Nigeria ..	1011·1	+0·2	97	64	88·7	71·3	80·0	−0·7	76·6	84	6·5	56·02	—	129	5·3	44
Kaduna, Nigeria ..	1009·3	—	100	52	88·2	65·2	76·7	−0·5	65·9	55	4·7	37·16	−16·67	95	7·7	64
Chileka, Nyasaland	1016·3	−0·3	98	51	83·3	63·9	73·7	+1·6	63·8	64	3·3	17·44	−18·64	70	7·4	61
Lusaka, Rhodesia ..	1013·9	−0·1	101	44	82·9	59·2	71·1	+2·1	60·0	65	3·3	23·38	−13·89	80	8·5	71
Salisbury, Rhodesia	1015·9	−0·3	94	37	77·9	54·5	66·2	+1·0	56·5	62	2·8	22·53	−10·91	69	8·0	66
Cape Town	1016·8	−0·2	102	38	72·7	54·8	63·7	+1·4	53·5	66	3·5	25·95	+0·91	120	—	
Palmietfontein, S. Africa	—	—	94	20	74·3	47·7	61·0	—	50·6	66	2·7	31·11	—	89	9·0	—
Mauritius	1015·9	−0·2	93	53	82·1	67·5	74·8	+0·8	67·8	69	4·4	38·95	−10·80	212	7·8	64
Calcutta, Alipore Obsy.	1007·3	−0·3	102	49	88·6	71·1	79·9	+1·1	72·8	76	3·5	65·02	+0·70	126	7·5	62
Bombay	1008·3	−0·9	101	59	87·9	74·5	81·2	+0·6	73·7	77	3·4	108·51	+36·32	124	7·3	60
Madras	1008·6	−0·2	108	62	90·8	74·7	82·7	−0·4	74·1	75	4·6	38·21	−11·35	84	8·3	69
Colombo, Ceylon ..	1009·9	+0·2	93	61	86·4	74·8	80·6	−0·4	74·8	83	5·1	96·26	+16·13	172	7·0	58
Singapore	1009·5	0·0	94	71	87·5	75·3	81·4	+0·5	76·3	81	5·8	84·26	−10·86	185	—	—
Hongkong	1012·8	+0·3	92	43	78·1	69·1	73·6	+1·3	68·7	80	—	82·74	−2·99	144	5·2	43
Sydney, N.S.W. ..	1016·5	+0·6	98	39	70·4	56·2	63·3	+0·2	57·7	73	4·6	66·26	+18·78	150	6·5	54
Melbourne	—	—	100	32	65·5	48·6	57·1	−1·3	51·4	69	5·5	31·41	+5·94	163	5·2	43
Adelaide	1017·9	+0·8	100	37	69·5	51·6	60·5	−2·5	—	—	4·6	18·23	−2·92	118	6·3	52
Perth, W. Australia	—	—	105	39	75·7	56·1	65·9	+1·7	58·8	61	3·6	27·15	−7·22	127	7·6	63
Coolgardie																
Brisbane	1016·4	+0·5	95	39	76·7	59·7	68·2	−0·7	61·5	66	3·9	47·18	+1·89	121	7·8	65
Hobart, Tasmania																
Wellington, N.Z. ..	1013·4	−0·8	77	35	59·9	48·2	54·1	+0·1	51·2	79	5·5	43·21	−4·83	158	5·8	48
Suva, Fiji	1011·5	+0·2	93	63	82·0	72·0	77·0	0·0	73·5	84	6·1	179·54	+62·40	269	4·9	40
Apia, Samoa ..	1010·5	+0·5	90	66	86·3	73·7	80·0	+0·5	76·8	80	5·0	117·66	+5·66	238	7·3	61
Kingston, Jamaica	1014·1	+0·4	94	65	88·1	71·9	80·0	+0·7	73·3	74	2·9	24·50	−9·09	69	8·2	68
Grenada, W. Indies																
Toronto	1017·0	+0·4	99	4	57·8	41·9	49·9	+4·7	42·2	76	5·9	24·84	−6·45	119	5·9	48
Winnipeg	1015·6	−0·6	105	−43	46·1	26·3	36·2	+1·6	28·8	—	5·5	22·96	+2·78	118	5·9	48
St. John, N.B. ..	1015·9	+1·3	87	−6	51·7	36·5	44·1	+2·9	39·3	83	6·5	52·21	+4·13	163	5·4	44
Victoria, B.C. ..	1017·2	+0·5	84	12	56·2	40·1	48·1	−1·3	42·1	88	5·7	35·46	+5·15	151	6·1	50

RAINFALL OF APRIL 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ..	2·12	138	*Glam.*	Cardiff, Penylan ..	2·68	107
Kent	Folkestone, Cherry Gdn.	2·85	172	*Pemb.*	St. Ann's Head ..	1·82	89
,,	Edenbridge, Falconhurst	3·31	189	*Card.*	Aberystwyth	2·90	141
Sussex	Compton, Compton Ho.	2·88	144	*Radnor*	Tyrmynydd	5·11	139
,,	Worthing, Beach Ho.Pk.	1·94	124	*Mont.*	Lake Vyrnwy	6·47	204
Hants	Ventnor, Roy. Nat. Hos.	2·03	121	*Mer.*	Blaenau Festiniog ..	11·26	182
,,	Bournemouth			*Carn.*	Llandudno	2·31	137
,,	Sherborne St. John ..	2·56	145	*Angl.*	Llanerchymedd ..	3·11	141
Herts.	Royston, Therfield Rec.	1·78	113	*I. Man.*	Douglas, Borough Cem.	4·34	178
Bucks.	Slough, Upton	2·23	156	*Wigtown*	Port William, Monreith	2·83	129
Oxford	Oxford, Radcliffe ..	2·14	134	*Dumf.*	Dumfries, Crichton R.I.	3·36	142
N'hant.	Wellingboro', Swanspool	1·91	128	,,	Eskdalemuir Obsy. ..	6·18	182
Essex	Shoeburyness	1·43	118	*Roxb.*	Kelso, Floors	1·71	109
Suffolk	Campsea Ashe, High Ho.	2·62	146	*Peebles*	Stobo Castle	3·57	171
,,	Lowestoft Sec. School ..	2·03	137	*Berwick*	Marchmont House ..	2·55	126
,,	Bury St. Ed., Westley H.	1·86	122	*E. Loth.*	North Berwick Res. ..	1·57	112
Norfolk	Sandringham Ho. Gdns.	2·26	149	*Midl'n.*	Edinburgh, Blackf'd. H.	1·98	135
Wilts.	Bishops Cannings ..	2·51	124	*Lanark*	Hamilton W. W., T'nhill	3·80	203
Dorset	Creech Grange.. ..	2·78	129	*Ayr*	Colmonell, Knockdolian	3·21	127
,,	Beaminster, East St. ..	2·81	119	,,	Glen Afton, Ayr San ..	4·53	151
Devon	Teignmouth, Den Gdns.	1·61	80	*Bute*	Rothesay, Ardencraig	4·04	136
,,	Cullompton	2·76	122	*Argyll*	L. Sunart, Glenborrodale	6·63	159
,,	Ilfracombe	2·35	112	,,	Poltalloch	3·87	128
,,	Okehampton, Uplands	3·64	114	,,	Inveraray Castle ..	6·95	151
Cornwall	Bude, School House ..	2·31	122	,,	Islay, Eallabus ..		
,,	Penzance, Morrab Gdns.	2·39	98	,,	Tiree	3·42	139
,,	St. Austell	2·99	106	*Kinross*	Loch Leven Sluice ..	2·59	135
,,	Scilly, Tresco Abbey ..	1·19	61	*Fife*	Leuchars Airfield ..	‡1·24	78
Glos.	Cirencester	2·67	143	*Perth*	Loch Dhu	5·41	114
Salop.	Church Stretton ..	2·63	121	,,	Crieff, Strathearn Hyd.	2·48	113
,,	Cheswardine Hall ..	3·29	188	,,	Pitlochry, Fincastle ..	2·70	121
Worcs.	Malvern, Free Library	2·00	111	*Angus*	Montrose, Sunnyside ..	1·27	70
Warwick	Birmingham, Edgbaston	1·96	113	*Aberd.*	Braemar	4·11	173
Leics.	Thornton Reservoir ..	1·65	97	,,	Dyce, Craibstone ..	1·90	92
Lincs.	Boston, Skirbeck ..	1·77	131	,,	Fyvie Castle	2·18	102
,,	Skegness, Marine Gdns.	2·38	178	*Moray*	Gordon Castle	2·74	157
Notts.	Mansfield, Carr Bank ..	2·35	136	*Nairn*	Nairn, Achareidh ..	2·67	191
Derby	Buxton, Terrace Slopes	4·83	164	*Inverness*	Loch Ness, Garthbeg ..	5·03	221
Ches.	Bidston Observatory ..	2·80	172	,,	Glenquoich	11·05	170
Lancs.	Manchester, Whit. Park	3·12	163	,,	Fort William, Teviot ..	7·47	166
,,	Stonyhurst College ..	3·93	145	,,	Skye, Duntuilm ..	4·57	141
,,	Blackpool			*R. & C.*	Tain, Tarlogie House ..	2·92	160
Yorks.	Wakefield, Clarence Pk.	2·61	155	,,	Inverbroom, Glackour..	8·71	234
,,	Hull, Pearson Park ..	2·49	160	,,	Applecross Gardens ..	6·12	179
,,	Felixkirk, Mt. St. John	1·91	114	,,	Achnashellach	11·15	208
,,	York Museum	2·64	165	,,	Stornoway Airfield ..	4·87	169
,,	Scarborough	2·51	161	*Suth.*	Loch More, Achfary ..	12·85	265
,,	Middlesbrough.. ..	1·88	137	*Caith.*	Wick Airfield	2·44	123
,,	Baldersdale, Hury Res.	2·91	120	*Shetland*	Lerwick Observatory ..	2·71	118
Norl'd.	Newcastle, Leazes Pk. ..	1·95	123	*Ferm.*	Crom Castle	4·80	188
,,	Bellingham, High Green	2·47	114	*Armagh*	Armagh Observatory ..	4·05	193
,,	Lilburn Tower Gdns. ..	2·21	112	*Down*	Seaforde	‡3·58	137
Cumb.	Geltsdale	2·65	124	*Antrim*	Aldergrove Airfield ..	3·68	175
,,	Keswick, High Hill ..	4·70	153	,,	Ballymena, Harryville..	4·90	186
,,	Ravenglass, The Grove	3·33	134	*L'derry*	Garvagh, Moneydig ..	5·68	233
Mon.	Abergavenny, Larchfield	2·17	86	,,	Londonderry, Creggan	5·75	224
Glam.	Ystalyfera, Wern House	5·63	148	*Tyrone*	Omagh, Edenfel ..	4·69	178

M.O. 533 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

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RECENT CLIMATIC TREND

By L. F. LEWIS, M.Sc.

The upward trend of temperature in the northern hemisphere has recently aroused a lively interest among meteorologists and others in Europe and America.

The 5-year volume of meteorological observations published by the trustees of the Radcliffe Observatory, Oxford, in 1932, contains an appendix by Dr. Knox Shaw and Mr. J. G. Balk giving, among other data, monthly values of mean temperature going back to 1815. The data were scrutinised by the authors of this appendix and corrections necessitated by changes of instrument and exposure were applied, and thus we have as homogeneous a set of observations as is possible over so long a period.

A detailed analysis of the data was made and published in *Professional Notes No.* 77*. In the latter part of the paper the figures were examined with reference to the secular trend of temperature and curves of 20-year running averages were drawn for the year and each of the four seasons. These curves, which are given in Fig. 1, have now been extended up to February 1950 and show some interesting and significant features.

The annual curve has continued to rise with minor fluctuations, and the final point on the graph representing the 20-year mean ending in 1949 is slightly higher than the previous record, which occurred in the 20-year means ending in 1836 and 1837. The winter curve fell from a large and extended maximum covering about the first 40 years of the 20th century to points well below the average in the 20-year means ending in 1947 and 1948. By February 1950 the curve had risen roughly to the long-period average, but as the curves are not smooth but irregular it may well be that the small minimum shown on this curve will prove to be part of a larger one. A similar value occurred in 1852 and 1853 during a minimum in that part of the 19th century.

The summer curve which has a minimum during most of the period of the recent winter maximum shows an equally significant change in the years since 1934. It has risen steadily and the value of the 20-year mean ending in 1949 is conspicuously higher than any previous 20-year mean throughout the whole period.

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*LEWIS, L. F.; Variation of temperature at Oxford, 1815–1934. *Prof. Notes met. Off., London,* 5, No. 77, 1937.

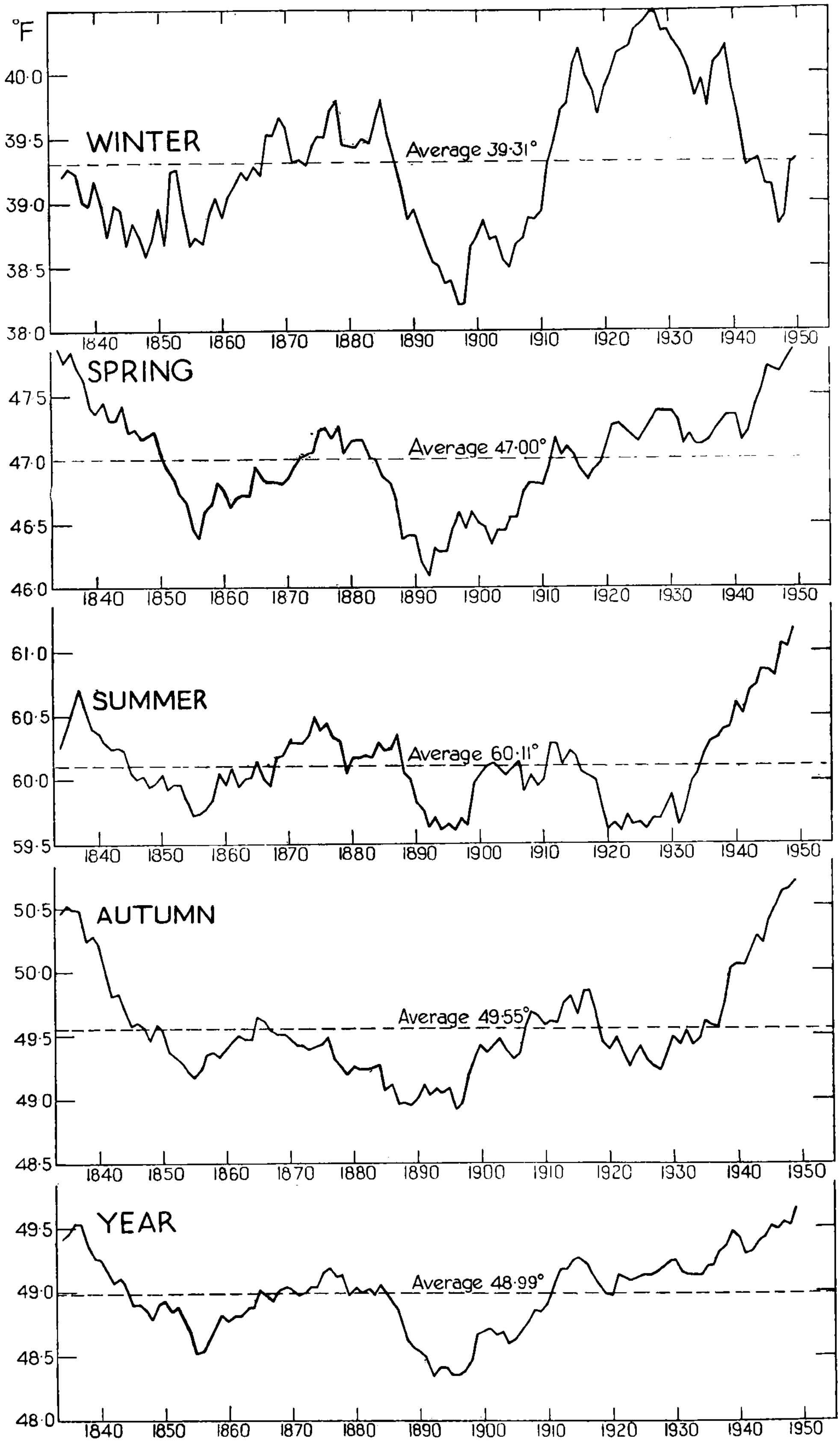

FIG. 1—OXFORD, 20-YEAR RUNNING AVERAGES TERMINATING AT THE STATED YEAR

The autumn curve shows changes similar to the summer curve, rising from a shallow minimum during the first part of the 20th century to a record high 20-year mean in the last 15 years.

The spring curve is very similar to the annual, and the mean for the 20 years ending in 1949 is practically equal to the previous highest means ending in 1834 and 1836.

Perhaps the most striking feature is the similarity between the beginning and the end of the curves, bearing in mind the long period covered by the data, and it is a temptation to suggest that in subsequent years the curves may, to some extent, be repeated. They will, however, continue to be irregular from point to point.

During the 15-year period since the figures were last analysed a number of records or near records have been established as is shown in the following table:—

(1) January 1940 was the coldest since the record cold January of 1838; mean temperature 29·2°F., 0·5°F. higher than in 1838.

(2) February 1947 was the coldest month during the whole period; mean temperature 27·3°F.

(3) March 1938 was the warmest March; mean temperature 49·1°F.

(4) April 1943 was the warmest April; mean temperature 52·1°F.

(5) August 1947 was the warmest August; mean temperature 66·3°F.

(6) September 1949 was the warmest September ; mean temperature 62·3°F.

(7) November 1938 was the warmest November since the record warm month in 1818; mean temperature 49·3°F., 0·6°F. lower than in 1818.

(8) The year 1949 was the warmest year ; mean temperature 51·6°F., 0·2°F. higher than in 1921.

UPPER FRONTAL ANALYSIS IN THE MEDITERRANEAN

By F. E. LUMB, M.Sc.

Upper cold fronts are not uncommon in the Mediterranean. Surface isobars may then be of no assistance in frontal analysis, especially if the isobaric pattern (or " constant-pressure-surface " pattern) changes rapidly with height. In placing upper cold fronts and estimating their present speed and future movement the contours of the 850-mb. surface are often useful. A good example is given by the front of October 10, 1948.

Example of October 10, 1948.—Fig. 1 shows the sea-level synoptic chart at 1500 G.M.T. on October 10, 1948. Fig. 2 shows the contours of the 850-mb. surface at 1500 also isopleths of the interval (thickness lines) between the 1000- and 850-mb. surfaces. Ascents for Tunis and Rome at 1500 were not available. The 0300 ascents were used with due allowance for solar heating as indicated by the 1500 surface temperatures. The figures for Sirte in Tripolitania were calculated, assuming a dry-adiabatic lapse rate up to 850 mb. (potential temperature 92°F.). This assumption is justifiable in hot desert air.

There is a striking contrast between the sea-level chart and the 850-mb. chart, due to the strong westerly thermal wind in the layer 1000–850 mb., which is a common characteristic of belts of easterly or south-easterly surface winds in the Mediterranean. At 850 mb. the thermal " low " over Tripolitania has disappeared, and the essential feature of the synoptic situation—a marked trough from Sicily to west Tripolitania—is clearly revealed.

The approximate position of the upper front is known from previous analysis, but the joint use of the 1500 sea-level and 850-mb. charts enables the position of the front to be fixed with a fair degree of accuracy. Also the 850-mb. contour chart enables the forecaster to assess the future movement of the upper front, for which purpose the sea-level chart is useless. Although the surface wind is easterly between Sicily and Tripolitania, the 850-mb. chart shows that the upper front can be expected to move slowly eastward in this region.

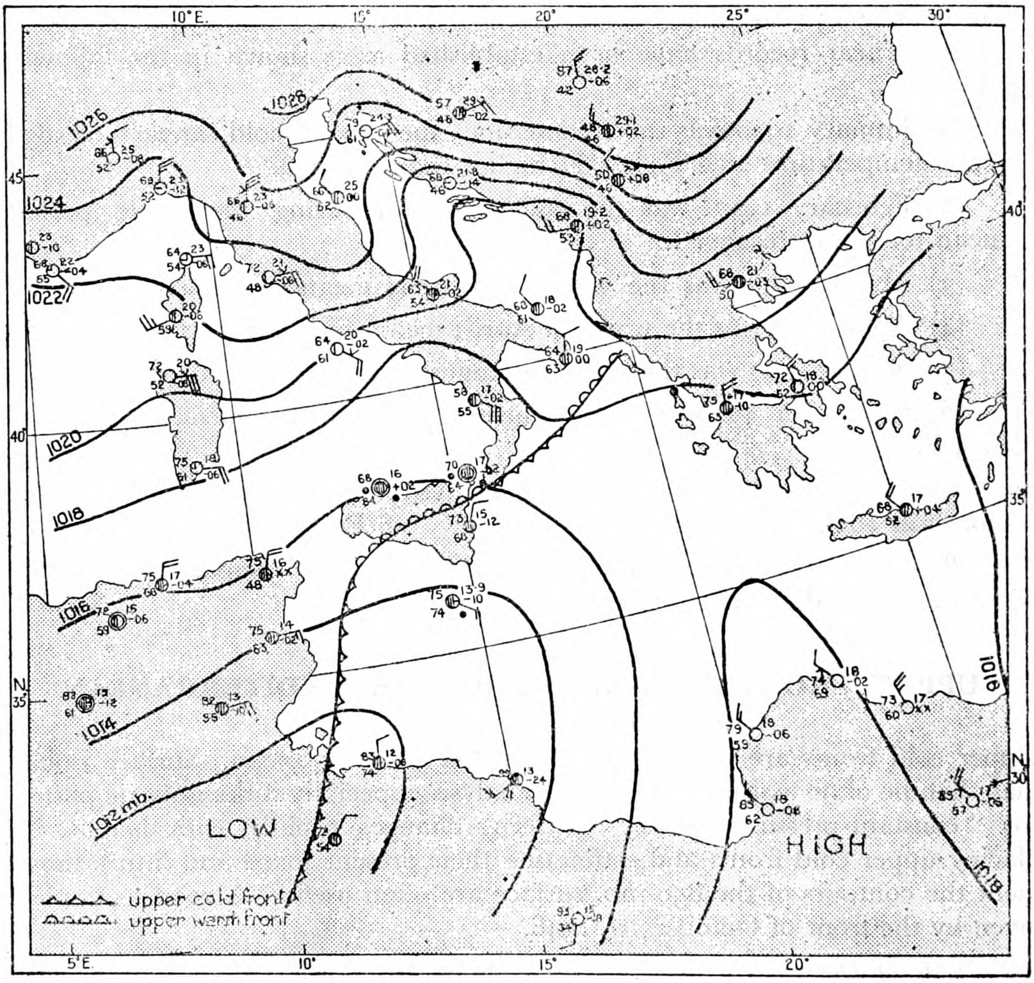

FIG. 1—SEA-LEVEL SYNOPTIC CHART, 1500 G.M.T., OCTOBER 10, 1948

Upper frontal analysis from thickness lines.—It has been shown how the 850-mb. contour chart can be used to tackle the problem of upper frontal analysis in the Mediterranean. The successful application of this method requires a good network of upper wind measurements at 850 mb.

In the *Meteorological Magazine* of July 1948 Dr. Sutcliffe* stresses the practical value of charts of thickness lines, and mentions their application to frontal

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*SUTCLIFFE, R. C.; The use of upper air thickness patterns in general forecasting. *Met. Mag., London,* 77, 1948, p. 145.

analysis. This line of attack is sometimes useful in detecting upper fronts when upper wind measurements to 850 mb. or higher are sparse or absent.

The essential clue to the presence of a thermally well marked, cold frontal surface on a thickness chart is a belt of relatively close thickness lines. The boundary of greater thickness is usually found close behind the axis of a " warm " ridge. For an upper frontal surface this boundary represents the foremost part of the cold air mass advancing aloft, *i.e.* the upper cold front, and can often be drawn with more or less accuracy, depending on the number

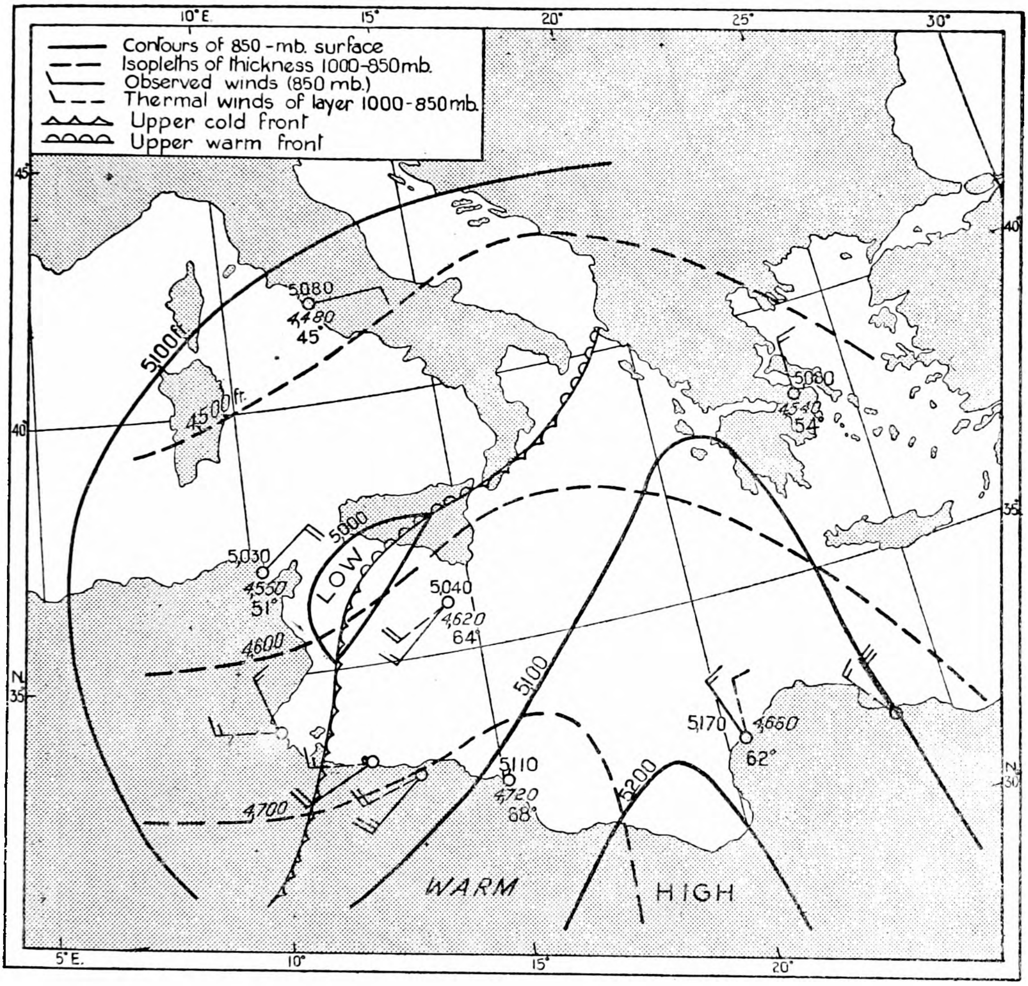
10°E.
15°
20°
25°
30°
Contours of 850-mb. surface
Isopleths of thickness 1000-850mb.
Observed winds (850 mb.)
Thermal winds of layer 1000-850mb.
Upper cold front
Upper warm front
45
40
35
N 35
N 30
5100ft.
4500ft.
5,080
4480
45°
5,080
4540
54°
5000
LOW
5,030
4550
51°
4600
5,040
4620
64
5100
5,170
4660
62°
5110
4720
68°
4700
5200
WARM
HIGH
5°E.
10°
15°
20°

FIG. 2—850-MB. CONTOUR CHART, 1500 G.M.T., OCTOBER 10, 1948
Heights are given in feet, temperatures at the 850-mb. level in degrees Fahrenheit

and spacing of upper air soundings in the vicinity of the upper front. A more precise position of the upper front can be drawn on the sea-level synoptic chart after combining a study of the thickness pattern with cloud and weather observations at the surface and from aircraft—also sometimes surface pressure tendencies.

In using this method of upper frontal analysis, due allowance must be made for the thermal wind component perpendicular to the frontal surface. As

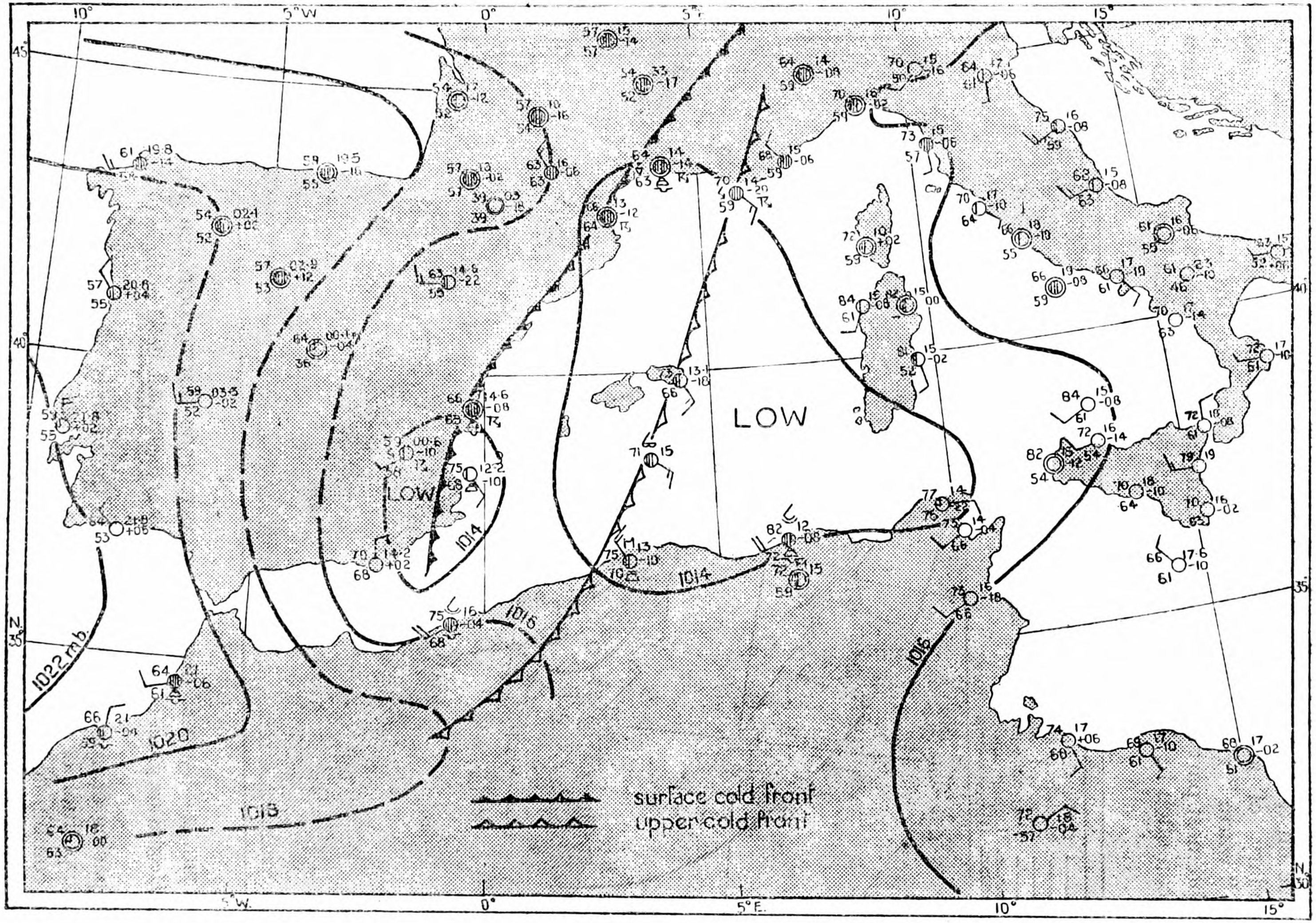
10°
5°W
0°
5°E
10°
15°
45°
40°
35° N.
30° N.
LOW
LOW
1014
1014
1016
1016
1018
1020
1022 mb.
surface cold front
upper cold front

FIG. 3—SEA-LEVEL SYNOPTIC CHART, 0300 G.M.T., AUGUST 18, 1948
Clouds types are shown only near fronts

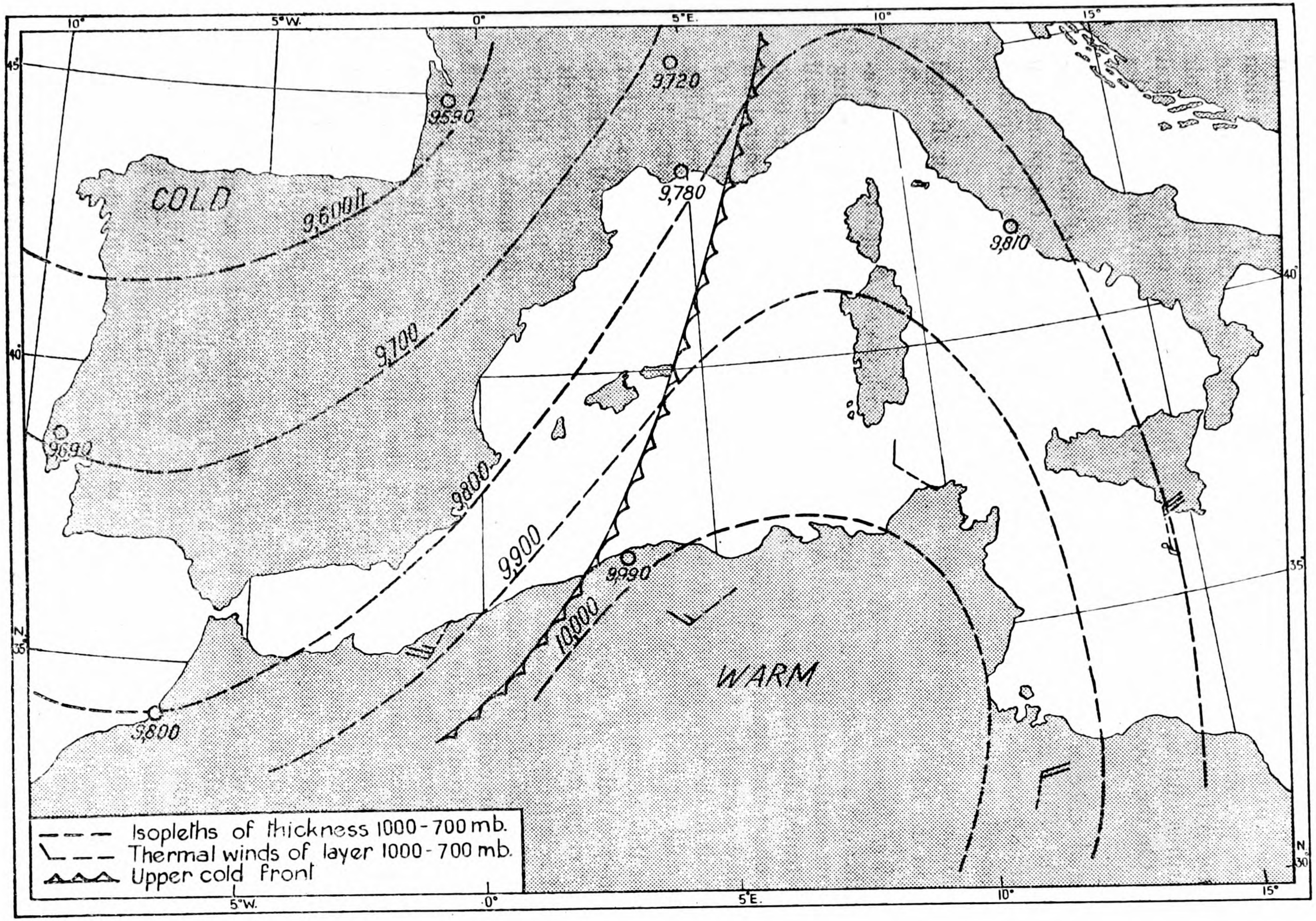
10°
5°W.
0°
5°E.
10°
15°
45°
40°
N. 35°
COLD
WARM
9590
9,720
9,780
9,810
9,600 ft
9,700
9690
9800
9,900
9,990
10,000
9,800
40°
35°
N. 30°
Isopleths of thickness 1000-700 mb.
Thermal winds of layer 1000-700 mb.
Upper cold front

FIG. 4—THICKNESS LINES AND THERMAL WINDS OF THE LAYER 1000–700 MB., 0300 G.M.T., AUGUST 18, 1948

Heights are given in feet

illustrated on p. 191, in the Mediterranean this component may be large in the layer from the surface up to 5,000 ft. and mask the normal relationship between thickness lines and cold frontal surfaces. However, for many upper cold fronts in the Mediterranean the component of the thermal wind perpendicular to the front in the layer from the surface up to 700 mb. is small. It is then sometimes possible to detect the belt of relatively close thickness lines and strong thermal winds, provided there are a few reliable soundings of upper air temperatures and upper winds to 700 mb. in the vicinity of the cold frontal surface. On the 1000–700-mb. thickness chart this belt is usually about 100 miles wide.

In the absence of upper wind measurements in the vicinity of the front, the movement of the upper front can be estimated by taking the component of the wind at 700 mb. perpendicular to the front, as deduced from the contours of the 700-mb. surface.

The following example illustrates the value of thickness lines for frontal analysis in the Mediterranean.

Example of August 18, 1948.—At 1800 G.M.T. on August 17, the surface observations indicated a surface cold front from west Germany to east Spain advancing slowly east-south-east. By 0300 on August 18 (see Fig. 3), the cold air had still not penetrated downwards to the east coastal stations of Spain. On the 0300 synoptic chart and again on the 0600 chart there was evidence of a general fall of pressure over the Mediterranean between Spain and Sardinia and of cyclogenesis in the vicinity of the Balearic Islands. This suggested the possibility that the cold air had already penetrated the west Mediterranean aloft.

To test this assumption it was necessary to study the thickness charts. That for 1000–700 mb. at 0300 on August 18 (Fig. 4) shows a well defined "warm" ridge over the western Mediterranean. Careful examination reveals a belt of relatively close thickness lines from Morocco to the Balearic Islands to the Gulf of Lions. The eastern boundary of this belt would mark the foremost part of the cold air mass advancing aloft, and its position was drawn as an upper cold front on the sea-level synoptic chart for 0300 (Fig. 3), and on the thickness chart (Fig. 4). It was drawn to be as consistent as possible both with the thickness pattern and also with the surface observations available at the time of analysis of the thickness chart, namely the 0300 and 0600 observations. The surface observations on both these charts were very sparse in the vicinity of the upper front, so that in this case the position shown is primarily based on the thickness chart.

This position was then checked by reference to the wind at 700 mb. determined from the absolute contours at 700 mb. The absolute contours at 700 mb. for 1500 on August 17 and 0300 on August 18 gave a fairly constant wind of 240°, 40 kt. close behind the front. The component at right angles to the front was therefore about 20 kt., and this speed is in good agreement with the distance travelled by the upper front between 1800 and 0300, assuming the 0300 position, found as described above, to be correct.

Subsequent charts gave ever increasing confirmation of the existence of the front, and by 2100 it could be traced quite easily on the sea-level synoptic chart (Fig. 5) by a trough extending from the depression over the Gulf of Genoa and an associated belt of thunderstorms over Tunisia and along the Italian coast.

The front passed through Malta as a weak upper cold front about 0500 on August 19. A comparison of the Malta soundings for 1500 on the 18th and 19th shows that the temperature up to 900 mb. had risen slightly, but had fallen above 800 mb. and especially between 830 and 730 mb. (about 6°F.). The upper front in the south was therefore probably about 4,000 ft. above sea level. Only in the extreme north, where cold air from the surface upwards had penetrated into the Mediterranean between the Alps and Pyrenees in the rear of the depression, was the front a typical surface cold front.

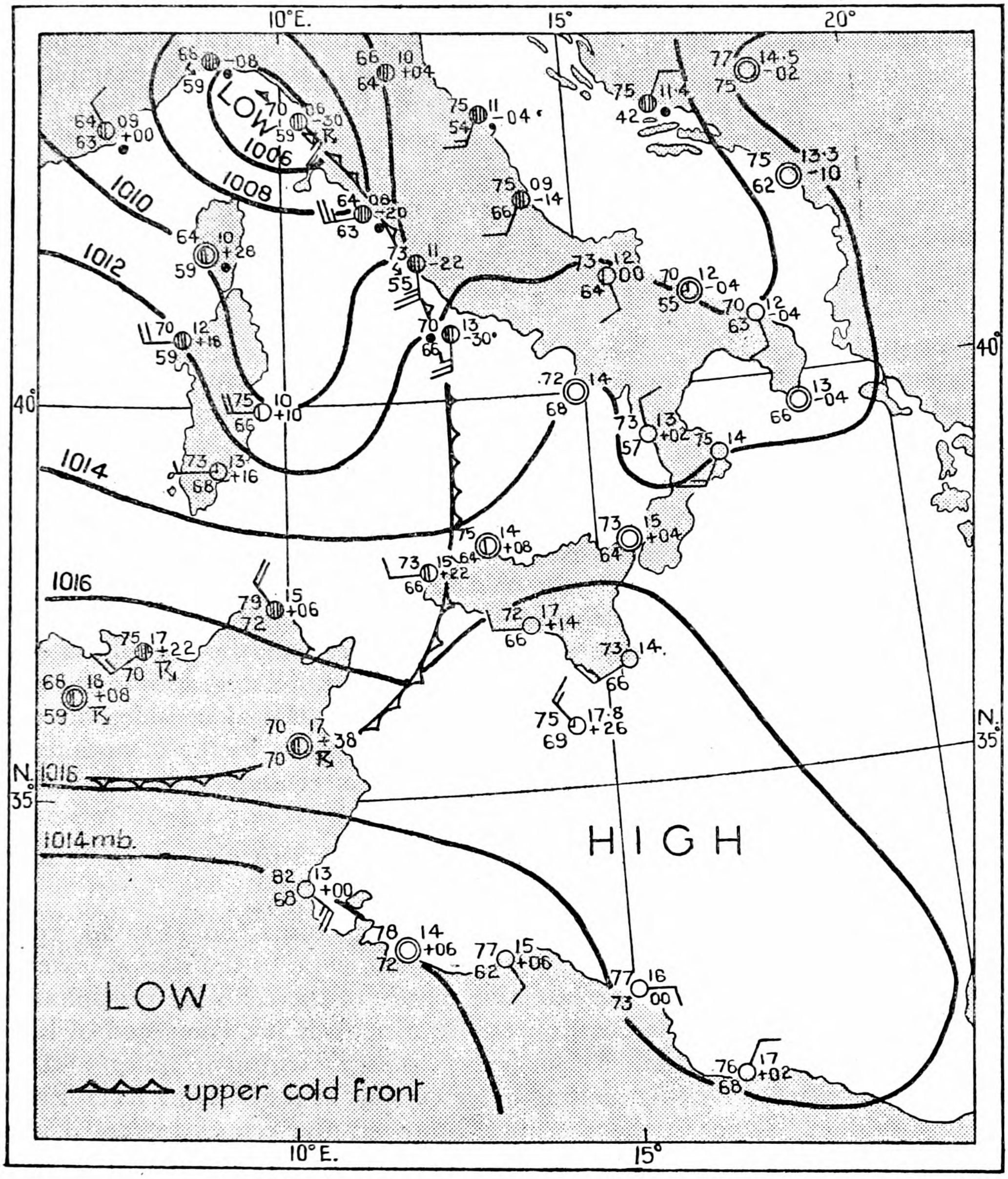
10°E.
15°
20°
40°
N. 35°
LOW
1006
1008
1010
1012
1014
1016
1016
1014mb.
HIGH
LOW
upper cold front
10°E.
15°

FIG. 5—SEA-LEVEL SYNOPTIC CHART, 2100 G.M.T., AUGUST 18, 1948

It should be noted that on the thickness charts it is the abrupt change of thickness gradient which is the essential characteristic of frontal surfaces.

For success in detection it is absolutely essential to resist the temptation to smooth out the thickness gradients. Rather should abrupt changes of thickness gradient be encouraged (within reason) to appear on the thickness charts.

RADAR WEATHER ECHOES

By R. F. JONES, B.A.

Part IV

Unusual weather echoes.—In the preceding sections typical photographs of the weather echoes in frontal situations have been given while examples of the weather echoes associated with cumulonimbus clouds have been given elsewhere[1]*. Usually the weather echoes observed conform broadly to the types described although, of course, each separate weather situation has its differences in detail. Occasionally, however, echoes are observed which depart considerably from the normal, and it is proposed in this section to give photographic examples of weather echoes of special interest together with their probable explanation.

Photograph (*a*).—This P.P.I. photograph was taken at 1014 G.M.T. on February 3, 1948, and shows, it is thought, the radar picture of a wave on a cold front. The synoptic charts, as given in the *Daily Weather Report*, show a cold front with waves extending east-north-east to west-south-west across south-east England and along the English Channel. Although this wave is not shown on the charts there seems little doubt of its existence.

The warm-front part of the wave to the north-east of the station† shows the characteristic diffuse edge, while the cold-front part to the north-west is more clearly defined and shows evidence of cellular structure. There is some fairly wide-spread precipitation in the warm sector as evidenced by the diffuse echo extending south-west from the station. Subsequent photographs show that the wave moved away eastwards, but the cold front trailed considerably and did not finally pass through the station until 1156 G.M.T. In the meantime the intensity of precipitation in the warm sector, as evidenced by the radar, increased considerably.

The photograph illustrates once more how the finer structure of the weather situation can be deduced with the help of radar.

Photograph (*b*).—This photograph, taken at 0850 G.M.T. on May 29, 1948, shows an unusually homogeneous response which, close to the station, extends to above 20,000 ft. Despite the extensive nature of the echo the precipitation reaching the ground at this time, on this bearing, was not composed of large enough drops to give a weather echo (except possibly within 10 miles) and the bright-band effect indicating melting of ice crystals at the freezing level is only weakly evident. Later in the morning, however, the echoes increased considerably in intensity and there was considerable rain over a wide area. It is thought that the echoes were received from large ice crystals which had grown to the requisite size to give a radar echo during their very slow descent against a wide-spread and fairly uniform upward current. The weak nature of the bright-band effect suggests that the ice crystals have only just reached the height of the freezing level on their descent. The echoes therefore suggest the existence of convergence taking place over a wide area and may therefore have been the first warning of the wide-spread rain which developed later. The synoptic chart showed the presence of a depression in the extreme north of France moving eastwards but without any front to account for the rain.

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*The index numbers refer to the list of references on p. 200.

†" Station " means East Hill, about 2 miles north-east of Dunstable, Bedfordshire.

The interpretation of the echoes is further confirmed by the report of a pilot who made an ascent at 0940 G.M.T. in the West Raynham area. He reported a continuous sheet of thin cloud from 6,000 ft. to " top not reached " at 29,000 ft. Throughout the ascent the sun was visible and conditions were quite smooth with no icing.

Photograph (*c*).—This H.R.T. photograph, taken at 1515 G.M.T. on July 4, 1949, on a bearing of 68° true, shows the response from precipitation falling from alto-cumulus castellatus cloud. At a height of 10,500 ft. in the column will be seen a brighter patch which is the " bright band " already referred to elsewhere. This patch indicates that the response from above 10,500 ft. comes from large ice crystals or snow-flakes. It will be seen that the echo decreases in extent and intensity below about 18,000 ft. and almost vanishes at 12,000 ft. This effect suggests that the base of the cloud was at about 18,000 ft. and that evaporation was taking place in the drier air beneath with a reduction in size of the snow-flakes or ice crystals and a consequent decrease in echo intensity. The ice crystals did not evaporate completely, however, and the echo increased again at 10,500 ft. as the ice crystals melted. Beneath 10,500 ft. the response was from rain and the increase in intensity again from about 6,000 ft. downwards suggests that the raindrop size was increasing in the lowest layers, probably by coalescence as the larger drops swept up the smaller in their path.

A further effect visible is the bending of the response caused by the increase of wind with height. The Downham Market upper wind at 1500 G.M.T. was constant in speed and direction at 248° true 36 kt. from 22,000 to 17,000 ft., and it will be seen that between these heights the echo column is vertical. From 17,000 to 10,000 ft. the wind decreased from 36 kt. to 25 kt., the direction remaining constant. The photograph was taken along the direction of the wind, and therefore shows the true effect of the wind increase with height. In falling from 17,000 to 10,000 ft. the echo column is displaced about 2 miles; the mean wind in this interval of height is $5\frac{1}{2}$ kt. (about 6 m.p.h.) less than the wind at 17,000 ft. and it follows that the snow-flakes or ice crystals took 20 minutes to fall from 17,000 to 10,000 ft. which gives a mean rate of fall of $1\frac{3}{4}$ m./sec. This rate of fall is in agreement with measurements made of the terminal velocity of large snow-flakes[2].

It would be expected that from 10,000 to 3,000 ft., where the precipitation was raindrops, the increased terminal velocity of the raindrops over that of the snow-flakes from which they were formed would be reflected in a more vertical column of echo, if the increase of wind with height was similar to the conditions above 10,000 ft. Although a change in inclination of the column to the vertical below the bright band is usually observed it is not so in this case. The deduced rate of fall of the raindrops is again of the order of 2 m./sec., and the only explanation can be that the fall of the raindrops was retarded by a considerable up current (of the order of 4 m./sec.) over a large interval of height. Examination of the radio-sonde ascent for this time (Downham Market 1500 G.M.T.) shows that, although the air was too dry to form cloud, convection currents could have occurred extending up to a height of about 7,000 ft. The existence of such an up current below 7,000 ft. may explain the increase in echo intensity in this interval by making coalescence of the raindrops more likely.

Photograph (*d*).—This is a photograph taken at about the same time (within 5 minutes) as photograph (*c*), and shows the type of cloud and precipitation from the cloud which gives the radar echo seen in photograph (*c*). It is almost certain that the cloud seen in the centre of this photograph is the one from which the radar echo of photograph (*c*), was received.

Photograph (*e*).—This photograph was taken at 1605 G.M.T. on July 28, 1948, on a bearing of 340° true, and shows the echo from an isolated thunderstorm which developed in conditions of exceptionally high surface temperature (over 90°F.) with little other cloud development for many miles around. The echo is unusually narrow (about 3–4 miles at its widest part) for a column of such great vertical extent—about 41,500 ft.—and suggests that the storm contained a single strong vertical current of air extending as far as the tropopause, instead of a number of up and down currents over a greater horizontal area which is usually the case in storms of such vertical extent.

Photograph (*f*).—This photograph was taken at 1234 G.M.T. on a bearing of 74° true during the thunderstorms of June 27, 1947, which were referred to by Douglas and Lewis[3].

The tendency for a bright band at 10,000–13,000 ft. in the echo nearest to the station is considered an indication of degeneracy in the storm close to the station with a reduction of the up currents to a very small value or perhaps to zero. The storm at 55–60-miles range is almost certainly the most active at this time.

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1. JONES, R. F.; Radar observation of heavy rain. *Nature, London*, **163**, 1949, p. 728.
2. HOOPER, J. E. N. and KIPPAX, A. A.; Interim report on measurements of radar echo from rain and snow. *T.R.E. Report No. T 2082.* Typescript, Malvern, 1947.
3. DOUGLAS, C. K. M. and LEWIS, L. F.; Thunderstorm of June 27, 1947. *Met. Mag., London*, **76**, 1947, p. 179.

METEOROLOGICAL RESEARCH COMMITTEE

The 59th meeting of the Committee was held on March 23. Reports from chairmen of the various sub-committees were received and the Research Programme for the forthcoming 12 months was approved. The Annual Report to the Secretary of State for Air was agreed.

The eighth meeting of the Instruments Sub-Committee was held on April 20. The papers considered included one by Mr. Grant[1] which describes the design of an aircraft thermometer with a very small lag. The solar radiation and lag errors of radio-sonde measurements were also discussed.

The ninth meeting of the Synoptic and Dynamical Sub-Committee of the Meteorological Research Committee was held in the Napier Shaw Laboratory at Dunstable on May 18, 1950. Members took this opportunity of viewing these new buildings and the work of the Forecast Research Division.

A paper by Mr. J. S. Sawyer[2] (" The formation and behaviour of cold-front waves ", giving the results of an investigation on wave disturbances on cold fronts, was discussed.

It was decided that the tephigram at present in use in the Meteorological Office should be modified to include the saturated adiabatics for condensation to supercooled water at temperatures below 0°C.

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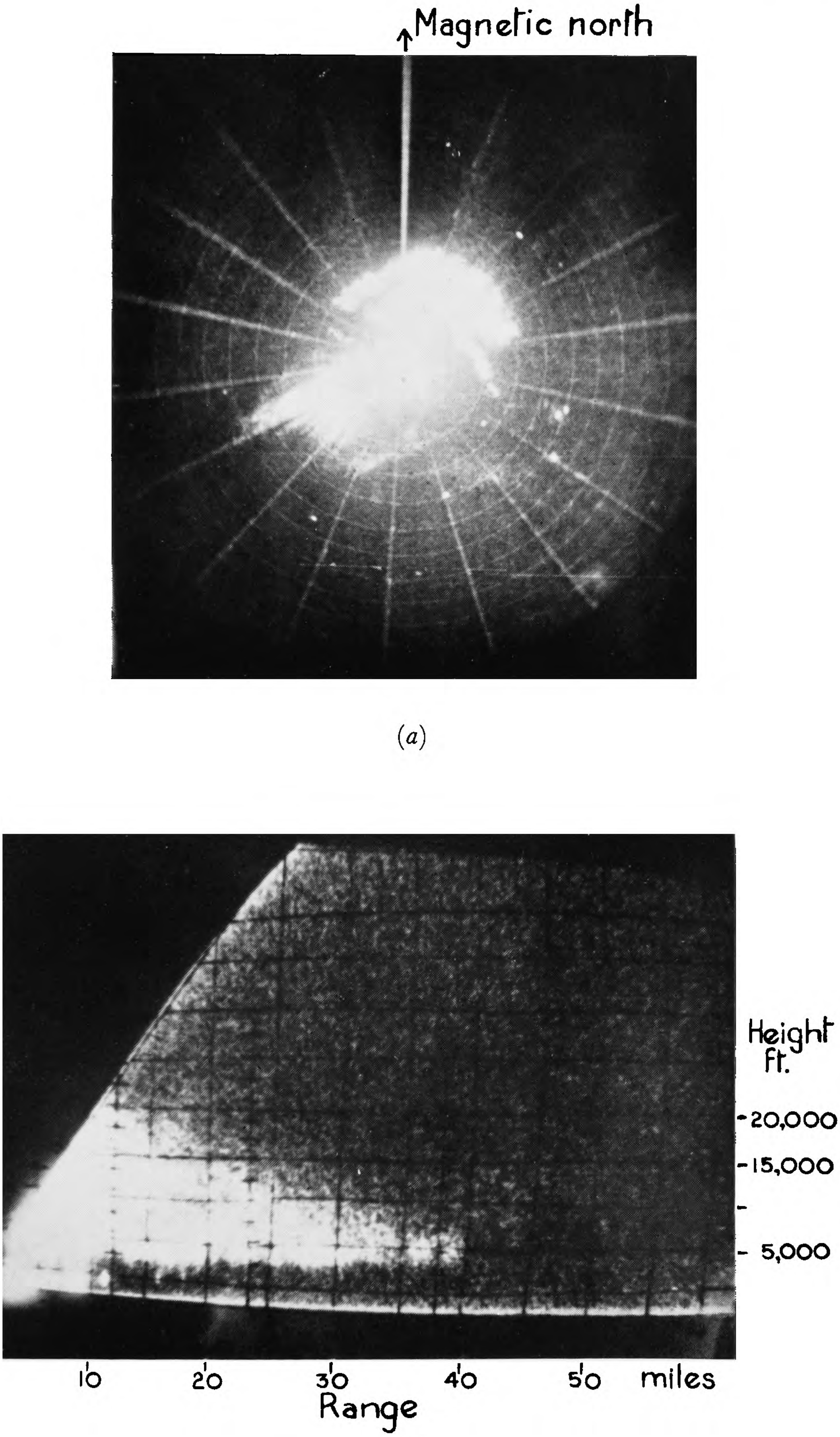
[1] *Met. Res. Pap., London*, No. 542, 1950.

[2] *Met. Res. Pap., London*, No. 553, 1950.

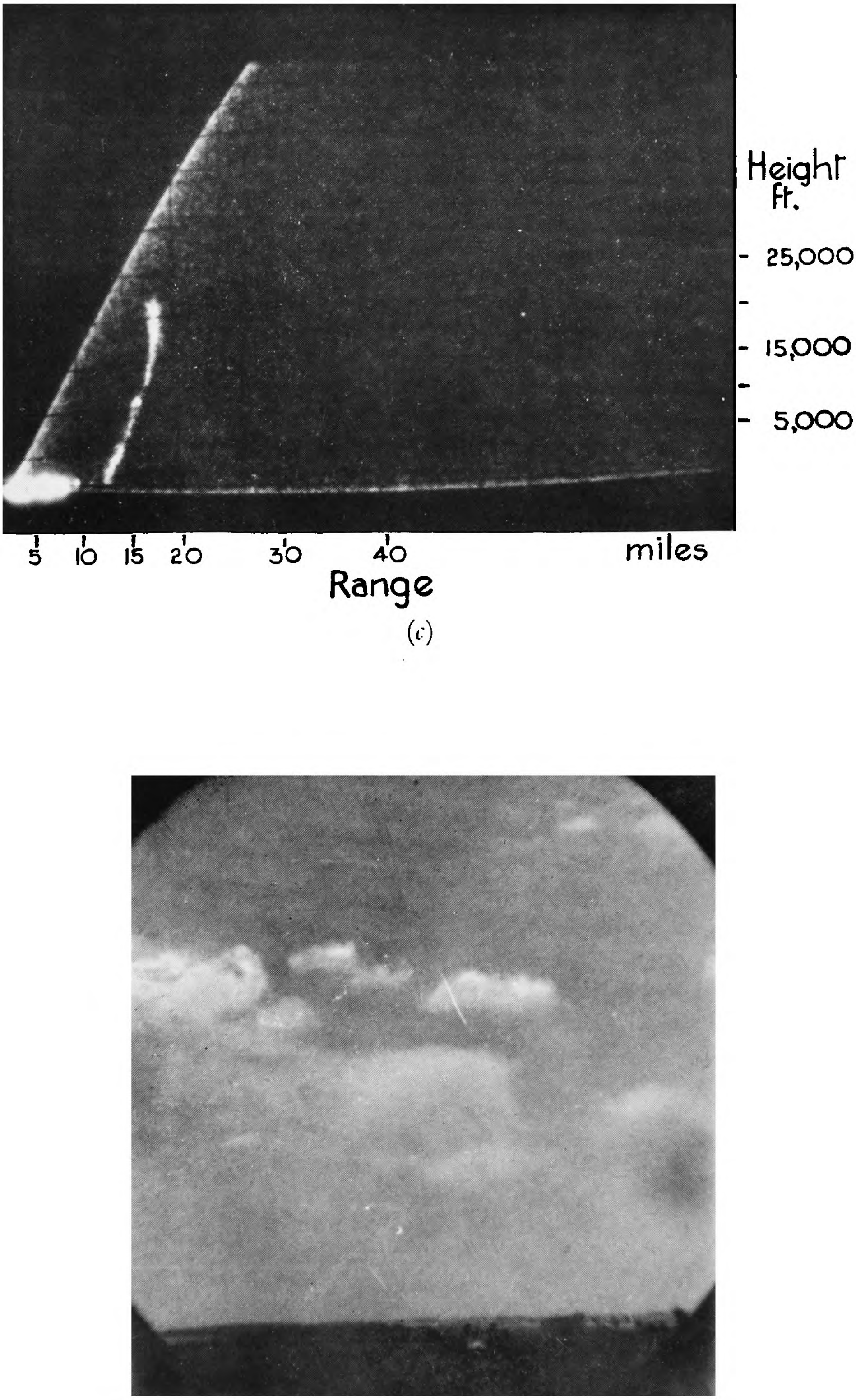

Magnetic north
Height
Ft.
20,000
15,000
5,000
10
20
30
40
50
miles
Range

(*a*)

(*b*)

UNUSUAL RADAR WEATHER ECHOES

(see p. 198)


Height
ft.
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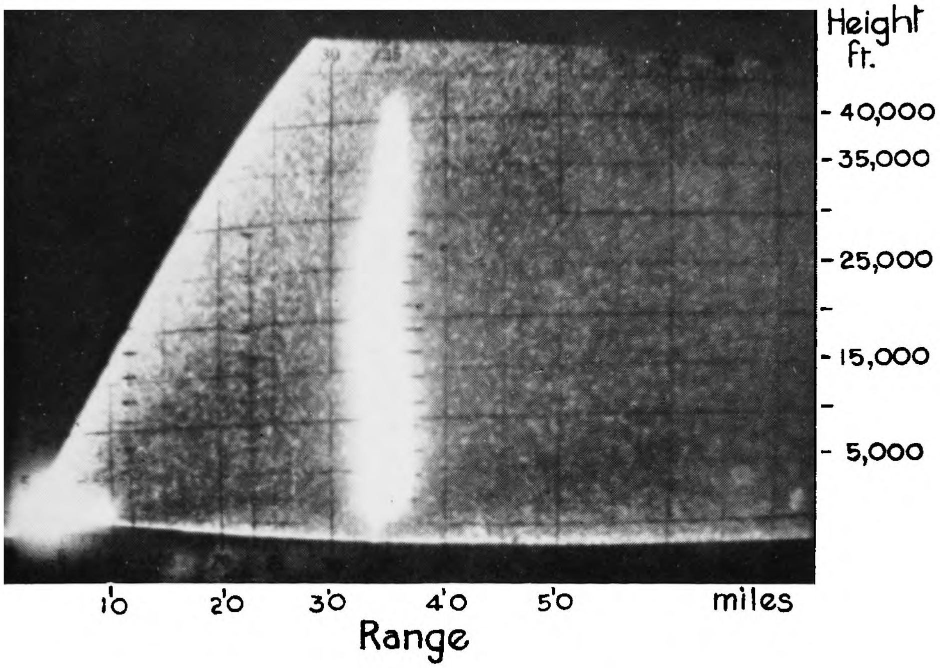
UNUSUAL RADAR WEATHER ECHOES

(see p. 198)



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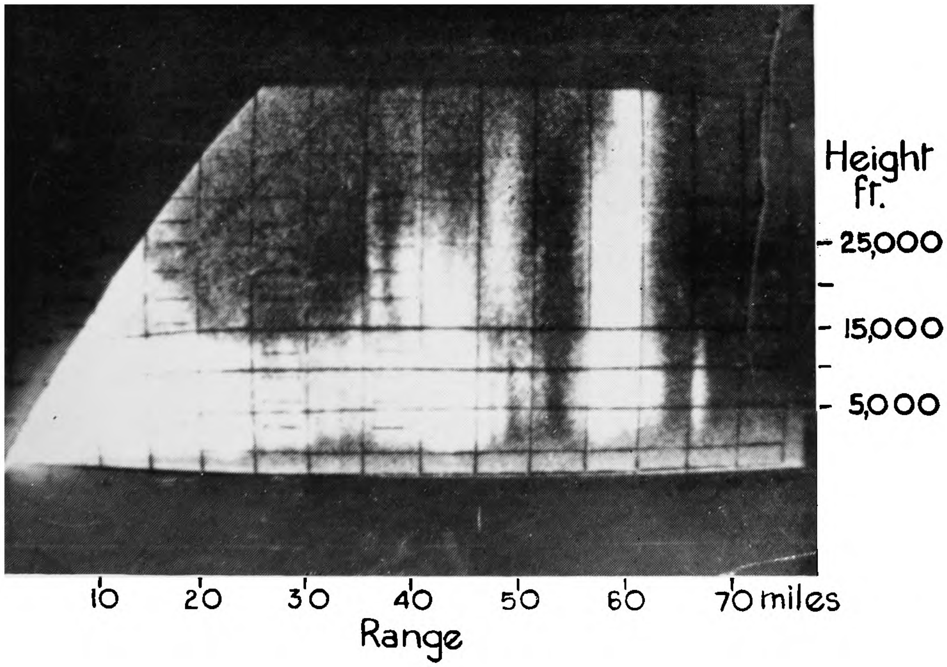

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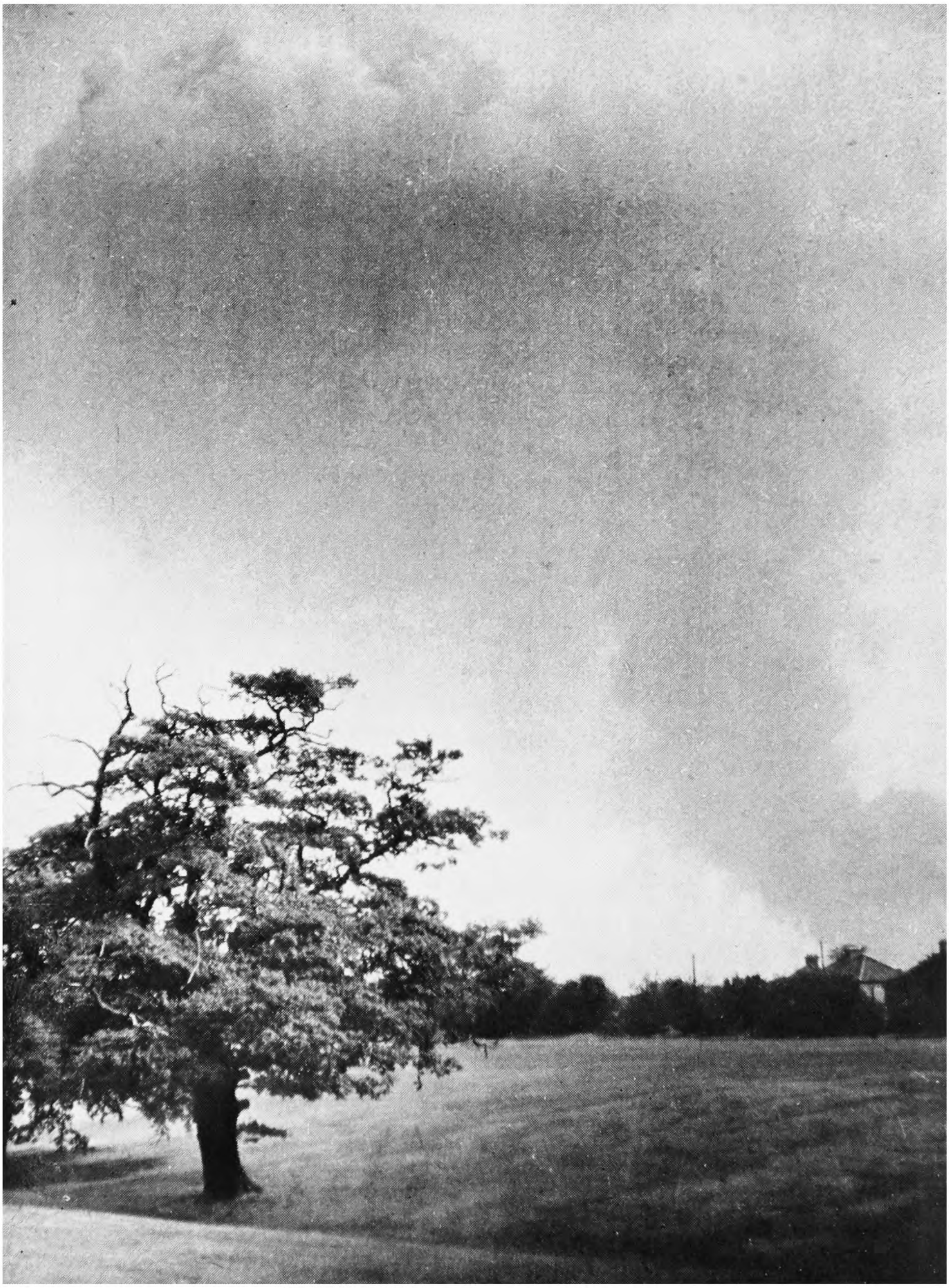
UNUSUAL RADAR WEATHER ECHOES

(see p. 198)



Reproduced by courtesy of R. M. Poulter

CUMULUS CLOUD FROM A FIRE

Column of smoke which produced a radar echo
(see p. 207)

Other matters discussed were jet streams, the variation of wind in short periods of time and over short distances, and the forecasting of winds at great heights over Empire air routes.

ROYAL METEOROLOGICAL SOCIETY

Three further reports on the symposia held at Oxford in late March are included in this number (see also *Meteorological Magazine* for June 1950, p. 173).

March 28, 1950, 3.30–6.30 p.m.: Radiation and its effect on the troposphere and lower stratosphere. Chairman—Sir Robert Watson-Watt.

Prof. A. Adel (Arizona State College, United States) opened with a paper entitled " The emission spectra of the earth's surface, the troposphere and the lower stratosphere ". From measurements of the emission spectra of the earth's surface in wave-lengths between 4μ and 14μ and the absorption spectra of the atmosphere over a similar range of wave-lengths he deduced that while the effective radiation temperature of the nitrous oxide in the atmosphere varies between 32°F. and 50°F., that of the ozone varies between –27°F. and –51°F., *i.e.* the nitrous oxide is concentrated mainly in the lower troposphere while the ozone is much higher.

Prof. T. G. Cowling (Leeds University) then presented a paper on " Calculating temperature effects due to radiation ". He said that, although much information was still needed about the absorption coefficients of the various atmospheric gases and their variation with temperature and pressure, he found that the results of calculations made with various different assumptions as to the missing information varied surprisingly little. He had applied his method to a few special cases, such as the discontinuity at the tropopause.

Mr. R. Goody (Cambridge University) spoke on " The experimental determination of the thermal state of the lower stratosphere ". He described recent experiments in the measurement of the infra-red spectrum of the sun from a high-flying aircraft, and gave some preliminary results on the water-vapour content of the lower stratosphere using this method. He also discussed the possibility of making total radiation flux measurements, and showed that such measurements would probably be difficult to make with the desirable precision. Lastly, he considered the possibility of measuring the turbulent-heat transfer in this region and discussed various indirect methods of obtaining the information required.

Dr. G. D. Robinson showed several examples of the use of the Elsasser radiation chart as modified at Kew over the lowest 50 cm. of atmosphere and over the layer down to a pressure of 500 mb. He found that the radiation effect in the lower 50 cm. on some occasions would give rise to a temperature change of ten to thirty times that actually observed.

Dr. T. W. Wormell (Cambridge University) confirmed the presence of nitrous oxide in the lower atmosphere.

Mr. A. W. Brewer (Oxford University) emphasised that, considering the atmosphere as a heat engine, the cold " sink " must be at lower pressure as well as at lower temperature than the hot " source ", so that the cold " sink " must reside in the upper atmosphere. The upper troposphere must therefore be cooling (by radiation) at an average rate of about 1°C. per day.

There was further discussion about the radiation chart and the desirability of having a simple and reliable means of estimating the radiational heating or cooling in the upper air that can be applied regularly in synoptic practice.

March 29, 1950, 2.30–6.30 p.m.: The structure of weather systems. Chairman—Dr. R. C. Sutcliffe.

A major controversy in this informative discussion was the relative importance of heating effects and of mechanical processes in the development of weather systems.

Dr. W. Bleeker (Netherlands Meteorological Institute) maintained that the jet stream was the result of differential heating, *e.g.* at the boundary between warm sea and cold continent. He showed, by means of simple diagrams, that the circulation arising from unequal heating at the surface caused a strong thermal gradient in the constant-pressure surfaces up above (at about 200 mb.), the temperature being lowest over the heated air and highest over the unheated. It was there, on the cold side of the upper boundary between the two air masses, that jet streams developed. The development was greatest where one circulation system reinforced another; indeed, secondary cold fronts were characteristic of all examples discussed by Durst and Davis[1]* and Palmén[2].

Dr. A. Nyberg (Swedish Meteorological Institute) said that the interaction of one circulation system on another was a factor in an empirical approach to forecasting frontogenesis; other factors were the slope and intensity of existing fronts. He had considered that the region of instability on the south side of a jet stream would have been a " breeding ground " for depressions; but, in the illustration shown (November 7–10, 1948), the jet stream appeared as the result, not the cause, of frontogenesis. In forecasting, one needed chiefly to be on the watch for areas of confluence.

Dr. W. L. Godson (Canadian Meteorological Service) stressed the necessity for upper air analyses and described the use of charts of frontal contours. These, drawn at intervals of 100 or 200 mb., are part of the forecasting routine of the Canadian Meteorological Service. He stated also that a double frontal system was necessary for intense cyclonic development. This was confirmed in the charts used for illustration: the two main depressions over North America at 1500 G.M.T., January 5, 1949, were each associated with waves, in phase, on the arctic and polar fronts.

With reference to the use of thickness charts, *Mr. J. S. Sawyer* showed from charts for May 1948, that Sutcliffe's formulae[3] for thermal development and thermal steering did, in fact, express what happened in the atmosphere. *Major Bundgaard* (United States Air Weather Service) referred to the forecasting of 24-hr. thickness by separate extrapolation of advective and non-advective components. These, *Mr. J. M. Craddock* had found to be negatively correlated.

Mr. A. G. Matthewman affirmed that cold air heated over the sea assisted the formation of depressions. This was confirmed by charts of the percentage frequency of cyclogenesis, 1899–1939, shown by *Dr. S. Petterssen* (United States Air Weather Service). In these, a zonal pattern was manifest, modified by local influences of sea surface and snow cover.

Prof. C. G. Rossby (University of Chicago) asserted that, in short-term changes, mechanical processes were more important than thermal, although the ultimate cause was thermal. His argument that jet streams did not always occur over regions of differential heating was countered by *Dr. Bleeker's* statement that transport of air in the lower layers frequently caused such displacement. *Dr. R. C. Sutcliffe* favoured Prof. Rossby's point of view.

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*The index figures refer to the list of references on p. 203.

REFERENCES

1. DURST, C. S. and DAVIS, N. E.; Jet streams and their importance to air navigation. *J. Inst. Navig., London,* 2, 1949, p. 210.
2. PALMÉN, E.; On the distribution of temperature and wind in the upper westerlies. *J. Met., Lancaster Pa.,* 5, 1948, p. 20.
3. SUTCLIFFE, R. C.; A contribution to the problem of development. *Quart. J. R. met. Soc., London,* 73, 1947, p. 370.

March 31, 1950, 9.30–12.30: Meteorology and the community. Chairman—Sir Robert Watson-Watt.

The opening speakers in this, the final symposium, were Sir Nelson K. Johnson, Sir David Brunt, Sir William G. Ogg, and Mr. N. R. Hagen (who deputised for Dr. Reichelderfer).

Although forecasting came in for some mention—one liked especially the reference to the 30-day forecasts in the United States which " were not published, though we allow the public to buy them "—the interesting, perhaps encouraging, fact was the attention to other applications of meteorology, and the indications of other fields to explore. Thus there was the work of the Meteorological Office in hydrology, which the *Director* was confident would soon become increasingly important to the national economy, and its active study of the weather problems of agriculture. With some apt examples, *Sir David Brunt* showed how the meteorologist's knowledge could have a decisive influence in the engineer's work—his remarks on smoke pollution being later underlined by *Dr. Sutton*—and called for a pioneering spirit among meteorologists to look for these applications and work on them.

Sir William G. Ogg (Rothamsted) led the speakers on " Weather and food " and called for a wider study of biological meteorology as a major contribution to agricultural production. Contributors on this theme were *Dr. Petersen* (Denmark) and *Mr. Simmers* (New Zealand) whilst *Dr. Penman* (Rothamsted) made a spirited appeal to physicists to come into work on agricultural meteorology, and to meteorologists to make sure they were getting the observations they wanted and no more.

Cdr. Frankcom was the voice of the mariner and described the effects of weather on the design and safety of shipping and the care of their cargoes.

On the subject of selling meteorology to the user interests, *Cdr. Hogben* called for meteorological " bagmen " to explore the industrial field generally—as the Meteorological Office was doing in agriculture—for applications of the knowledge we already had—not necessarily only from the forecast angle, but for planning applications. And *Mr. A. H. Yates* (College of Aeronautics, Cranfield) wanted a quick resumption of AIRMET as the best method of getting up-to-date weather information over to a variety of users.

All these contributions made one realise the need for bigger and better meteorological services to allow as much concentration on industrial and other problems as has been given to aviation. And if one wondered where the money was coming from, Mr. Hagen and Mr. Saunders had an answer—" Show the business man that you can save him money and you'll get his support ".

MEETING OF THE CHALLENGER SOCIETY

At the 167th scientific meeting of the *Challenger* Society, held in London on April 19, a paper of exceptional interest " Problems and new techniques for the present-day oceanographer " was read by Mr. C. O'D. Iselin, Director of the Woods Hole Oceanographical Institution, Massachusetts, United States. The good work of the Woods Hole Institution is well known, and the paper aptly illustrates the wide range of activities upon which American oceanographers are engaged.

Mr. Iselin's paper was solely concerned with the North Atlantic, and discussed such items as the distribution in depth of the 10°C. isotherm; the vagaries of the Gulf Stream, both at the surface and in depth, and a section through its temperature profile; the practical use of the bathythermograph; the practical value of " Loran " to the oceanographer, particularly when obtaining details of surface current movement; an ingenious electro-magnetic method of obtaining ocean-current observations from a moving ship; and experiments with sonic waves of various frequencies to determine the nature of " layer " echoes at varying depths in the water of the oceans.

Although he did not mention meteorology as such, Mr. Iselin's paper did much to emphasise the intimate and inescapable relationship between meteorology and oceanography, and indeed of the necessity of those engaged upon these two sciences getting together and generally co-operating. The contours of the 10°C. isotherm, for example, followed in a remarkable way the track of the Gulf Stream and North Atlantic Drift at the surface—thus showing that the warming effect of the Gulf Stream is effectual at considerable depths, and that there is perhaps also a similar drift effect across the ocean at such depths. This fact is undoubtedly of great meteorological importance. Another striking feature was the curious waves or swirls which have been shown to occur in the southern extremity of the Gulf Stream. These swirls have been investigated by the Woods Hole Institution in considerable detail, and it seems that they are, to some extent, analagous to the waves which occur at frontal " meeting places " in the atmosphere near the earth's surface. The whole thermal structure of the oceans and particularly its intricate pattern at the edge of the Gulf Stream was vividly described in slides, and this also seems to be of considerable meteorological interest for it is certain that the vagaries in the ocean temperature have very great effect upon the overlying atmosphere.

There seems little doubt that the use of electronic aids to navigation (" Loran " in this case) is an enormous boon to the oceanographer, who can thus obtain regular " fixes " quite irrespective of atmospheric conditions, and enable very accurate ocean-current observations to be made merely by letting the ship steam a steady course at slow speed. The electro-magnetic apparatus which Mr. Iselin referred to is towed astern of the ship and depends broadly for its action upon the magnetic force of the earth and the currents induced in sea water flowing across or along the magnetic field; if there is no ocean current present, then there is no electrical disturbance on the instrument. To operate the instrument a ship needs to steer various courses so as to steam across the current in order to get its maximum effect. The sonic sounding experiments showed that many of the false echoes which appeared on the trace are due to living organisms of some kind or other in the water, and that by varying the frequency of the transmission one can get echoes from different sizes of organisms.

C. E. N. FRANKCOM

LETTER TO THE EDITOR

Unusual fall of rain at Upavon on November 4, 1949

During the afternoon of November 4, 1949, an outbreak of rain occurred at Upavon. Evidence available suggests that this rain fell from a layer of stratocumulus, the top of which was at a temperature above the freezing point. Such rainfall is comparatively rare, at least in temperate latitudes.

The 1200 G.M.T. synoptic chart showed that the Upavon area was in warm air, a warm front lying well to the north across the north Midlands and central Ireland. The morning ascents at Larkhill and Camborne suggested that a sheet of stratocumulus would spread across south England during the day. The cloud sheet reached Upavon about noon with the base estimated at 1,800 ft. above station level. It was anticipated that any precipitation occurring at Upavon during the afternoon would be very slight and take the form of drizzle.

By 1400 it was evident that the stratocumulus to the south-west of the station was thickening and that the base was becoming lower. A balloon sent up shortly after 1400 indicated broken cloud at 1,200 ft., with the main layer at 1,500 ft. Visibility also fell from 6 miles at 1300 to 3 miles at the time of the balloon ascent. At 1450 approximately slight drizzle commenced, but within about five minutes this drizzle had turned to rain, which continued for nearly an hour, gradually turning to slight drizzle again at 1600.

There was no doubt that the precipitation was rain and not heavy drizzle—it first drew my attention beating up against the windows. The fall was sufficiently heavy for water to run off the roof and down the fall-pipes within five minutes of its commencement, and was splashing in the puddles in the road. Other members of the staff agreed that it was definitely rain that was falling.

At about 1520, when the rain was still falling steadily, W/Cdr. W. E. Gardiner, D.F.C., A.F.C., landed on the airfield in a Proctor aircraft, having flown from Abingdon. He telephoned the Meteorological Office almost immediately with the following report.

Over the airfield and surrounding districts there was an 8-eighths layer of stratocumulus, roll topped. He had been flying along the top of the layer and had been flying in and out of cloud between 5,500–5,800 ft. (heights above M.S.L.). This would give the cloud top over Upavon as between 4,920 and 5,220 ft. (Upavon is 580 ft. above M.S.L.). Above the stratocumulus there was 4 eighths of thin altocumulus, base unknown. The altocumulus was in large patches, mainly towards the west. No precipitation was experienced whilst flying in the cloud tops. The upper part of the stratocumulus cloud was very tenuous, the sun being visible when several hundred feet inside the cloud. There was no turbulence. Descending through the cloud sheet, drizzle was encountered between 3,000 ft. (above M.S.L.) and the base of the cloud which he gave as 1,500 ft. (above M.S.L.). Thus the layer in which precipitation occurred was between 2,420 and 920 ft. above Upavon. The cloud between these levels was much denser than higher up, and there was marked turbulence. No temperatures were recorded.

The 1500 ascent from Larkhill (440 ft. above M.S.L.), situated 5 miles south-west of Upavon, showed that, in the general south-westerly current prevailing, the balloon must have been near Upavon during its ascent and there appears to be little reason for supposing that the ascent was not representative of the conditions in the Upavon area about the same time. The ascent indicated that the top of the stratocumulus layer was at 850 mb. (4,678 ft. above Larkhill) whilst the freezing level was at 6,238 ft. The presence of thin altocumulus was also indicated at about 750 mb. The dew-point curve suggested that precipitation was unlikely to occur from this medium layer.

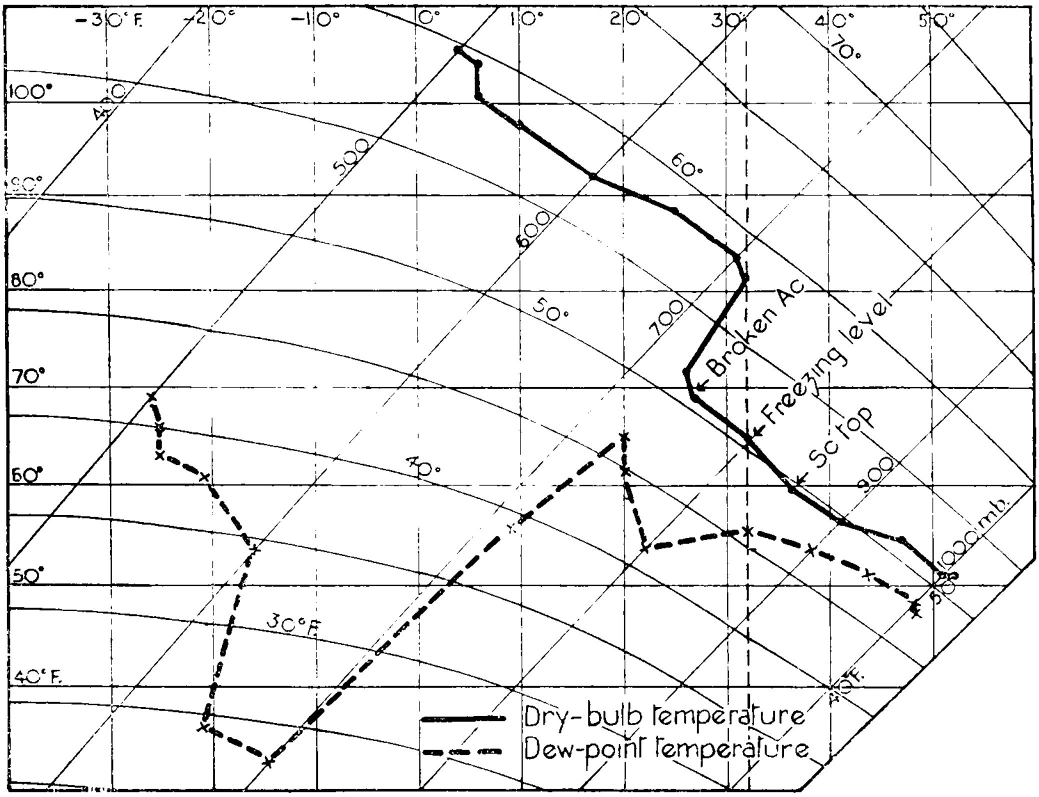

FIG. 1—RADIO-SONDE ASCENT FROM LARKHILL, 1500 G.M.T., NOVEMBER 4, 1949

There seems little reason to expect a large variation in freezing level over the distance between Larkhill and Upavon, and allowing for the difference in heights the freezing level at Upavon was about 6,100 ft., almost 1,000 ft. higher than the top of the cloud layer. The presence of ice crystals in the cloud was therefore impossible. It seems therefore that the rain that fell was the result of the coalescence of small water-drops in the lower part of the cloud. The fact that turbulence was in this part only may be significant.

The rainfall was very local. A check was made on surrounding stations but, with the exception of Netheravon, 3 miles south of Upavon, no precipitation had occurred up to 1600. At 1600 Boscombe Down, 10 miles to the south, reported intermittent slight drizzle. The lowering of the base of the stratocumulus cloud was generally remarked upon.

Upavon, Wiltshire, November 17, 1949 E. J. KINSHOTT

NOTES AND NEWS

Ocean weather station JIG—a joint Anglo-Dutch station

On April 15, 1950, the Netherlands' ocean weather ship *Cumulus* took over duty from the British *Weather Recorder* at station JIG, lat. 52°30'N., 20°00'W.;

this is the first occasion British vessels have shared the operation of an ocean weather station with one of another nationality. *Cumulus* will perform five 21-day periods of duty at JIG in 1950 thus doing alternate duties with three British ships which will be able to have well deserved " lay-up " periods.

While on duty *Cumulus* will carry out the same general meteorological and oceanographical procedure as her British colleagues, using the same radio channels to Dunstable and Prestwick though she will also communicate direct with Holland. R.A.F. aircraft will drop mails and carry out exercises as with the British ships.

Cumulus was originally a United States Navy frigate and is considerably bigger than the British vessels.

On the arrival of *Cumulus* at JIG her Master and crew were greeted with traditional maritime courtesies by the Master and crew of the *Weather Recorder.*

Radar echo from smoke

The photograph facing p. 201 of this Magazine shows a cumulus cloud produced by a fire of bales of cork at Hayes (Middlesex) on August 18, 1949. The photograph was taken by Mr. R. M. Poulter at 1400 G.M.T. looking south-south-east from Hillingdon, a distance of 2½ miles from the fire. This column of smoke produced the radar echo illustrated in the *Meteorological Magazine* for March 1950 (facing p. 80). The estimated height of the cloud top is 5,000 ft.

REVIEW

Electric charges on rime-covered surfaces. By C. Kramer. Koninklijk Nederlandsch Meteorologisch Instituut No. 102. Mededeelingen en Verhandelingen, Serie A, No. 54. 8vo, 9½in. × 6¾ in., pp. 128. *Illus.* 's Gravenhage, 1948. 3·00 florins. Dutch with English summary.

The importance of the work of Findeisen and Lange, published in the *Meteorologische Zeitschrift* between 1940 and 1943, on the electrical phenomena accompanying the growth, evaporation, and splintering of ice crystals is now becoming widely recognised. Dr. Kramer has repeated the German experiments but was not able to confirm them in all respects. The positive charging of a body upon which rime is being deposited was found by Kramer to cease as soon as the first uniformly oriented layer of crystals was deposited on the surface, and, during the subsequent further growth of the layer, it was found that the potential of the body decreased showing the development of a negative charge. Findeisen found a marked positive charge was produced when super-cooled water droplets froze on to ice crystals but Kramer obtained a negative charge. Kramer found the rate of charging of the body on which rime was being deposited to be proportional to the velocity of the air current, and a sudden increase in this velocity led to a strong positive increase in the potential. Kramer's experiments included efforts to detect complementary charges in the air, and these were found to have the right sign when sudden changes in the potential of the test body were made but were difficult to measure when the growth of the charge on the test body was gradual. Findeisen's observation that a growing layer of rime throws off negatively charged " splinters " was repeated with confirmation of the " splintering ". Relatively few of the splinters, however, were noticeably charged though most of those with appreciable charge were negative.

These effects are of great importance to the physics of cloud formation, since the " splinters " provide sublimation nuclei, as well as to the generation of electric charge in clouds, and meteorologists will be grateful to Dr. Kramer for his work in a subject in which the experimental difficulties are great.

G. A. BULL

METEOROLOGICAL OFFICE NEWS

Exploration.—The ships *William Scoresby* and *Discovery II*, under the direction of the newly formed National Institute of Oceanography, have now sailed on voyages of about two years' duration, the first to the Indian Ocean and the second to both the Indian Ocean and the Antarctic Ocean. In addition to making normal meteorological observations, the *Discovery II* will make cloud-height observations with " free " balloons.

Publicity.—An illustrated pamphlet with the title " Your Weather Service " is being published by the Central Office of Information with the object of bringing the activities of the Meteorological Office to the notice of the public. The book lays special emphasis on the services which the Office can provide for public bodies and private individuals in both the forecasting and climatological fields. There is also a useful section on the interpretation of weather forecasts.

Assistance to farmers.—Detailed information about recent weather can sometimes be of as much value to the farmer as forecasts of future weather. For example, if potatoes are sprayed within a week of a period of continuously warm and humid weather, the spread of potato blight can be controlled or even prevented. For this reason arrangements have recently been made in consultation with the Plant Pathology Laboratory of the Ministry of Agriculture by which the Meteorological Office issues warnings whenever the conditions which are believed to lead to blight have occurred.

To provide agricultural scientists with a brief summary of current weather, the Meteorological Office has also begun to issue a weekly weather summary to about 300 officers of the National Agricultural Advisory Service. The summary gives details of the weather each day, departures from average of the weekly sunshine, rainfall, air and soil temperatures and statistics of the rainfall as well as calculated losses of moisture by transpiration and also details of the incidence of frost. The summary is prepared for each of the eight " provinces " of the Ministry of Agriculture in England and Wales, and reaches recipients within a week of the period to which the summary refers.

Radio-sondes.—In the June number of this Magazine, reference was made to the trials at Payerne, Switzerland, of different types of radio-sonde instruments. The instruments compared were Finnish, German, French, Swiss, two types from the United States and the British. The personnel taking part also included delegates from Belgium, Holland, Norway and Sweden. Two or more different types of sonde were attached to the same balloon and corresponding readings of pressure, temperature and humidity were evaluated for each minute. In very favourable conditions it was found possible to launch six radio-sondes, one under the other, the lift being supplied by three balloons. Ascents were made at about 1500 and 2100 local time, and the same combination of sondes used for each ascent on the same day in order to obtain information about the differences between day and night soundings. The results of the comparisons are now being worked out.

Helicopters.—Helicopters of British European Airways on the passenger service between Liverpool and Cardiff which started on June 1 fly without radio operators on board. In consequence, broadcasts by radio telegraphy of meteorological information cannot be received by the pilots while in the air. To cover the deficiency special arrangements have been made to provide meteorological information by radio telephony on request.

Radiation recording.—For some years, a programme of investigation into various methods of recording radiation has been carried out at Kew Observatory, and this programme is now being extended to other stations. One instrument for measuring total radiation on a horizontal surface and another for measuring the diffuse radiation from the whole sky, but not from the direct sun, are being supplied to Lerwick, Eskdalemuir, Aberporth and Mildenhall. These instruments are described in the *Meteorological Magazine* for February and March, 1936, and further details will be given in *Geophysical Memoirs* No. 86, to be published shortly. A simpler type of bimetallic radiation recorder is also being sent for trial to a number of stations.

Recruitment of assistants.—It is satisfactory to be able to report that there has been a good response to the intensified recruiting campaign referred to in the March number of this Magazine. Assistants serving at under-staffed units should shortly begin to feel the benefit of the new arrivals.

No small share of the credit for this happy result belongs to senior Meteorological officers and other officers-in-charge who helped by visiting local labour exchanges, youth employment offices and schools and by personal discussion with prospective candidates.

R.A.F.V.R. Meteorological Section.—Each member of the meteorological section of the R.A.F.V.R. is normally " affiliated " to a neighbouring R.A.F. station having a suitable meteorological office. Attendances for non-continuous training are then made on occasional evenings and at week-ends. Affiliations have now been completed. At one R.A.F. station near London where there are several reservists it has been possible to arrange attendances in such a way that all the meteorological work needed by the Royal Auxiliary Air Force Squadrons on the station is done by the reservists.

Central Forecasting Office, Dunstable.—A magazine entitled *Halcyon*, devoted to " gossip, news and jest about the folk at the Meteorological Office, Dunstable " has recently been started by the staff there. It is expected that five or six numbers will be issued each year. The latest number gives the office bearers of the Sport and Social Club for the current year. They are Mr. E. G. Bilham (Chairman), Dr. A. G. Forsdyke (Treasurer) and Mr. T. H. Clifton (Secretary).

Sports activities.—We would offer our congratulations to :—

Miss D. J. T. Ayres, on being chosen for the Civil Service hockey team ;

Mr. P. E. Hammerton, 16 years of age, on being chosen to play for the Civil Service Chess team against Combined Oxford and Cambridge Universities;

Mr. R. E. Farms on being runner-up in the scratch and handicap competition for the Air Ministry Golf Championship;

Mr. R. E. Farms and Mr. G. J. W. Oddie on being selected as two of a team of three to represent the Air Ministry in the Lloyd George Civil Service Golfing Cup and on winning both their matches;

Relay Team, Meteorological Office, Uxbridge, on winning the relay at Uxbridge Royal Air Force Sports;

Cpl. A. F. Lewis and L.A.C. D. A. Abott on being selected to play water polo for the R.A.F. during their recent London tour. Mr. Lewis, who holds two Air Ministry Swimming Championships, played in every match and was leading goal scorer during the tour.

NEWS IN BRIEF

The following award was announced in the Birthday Honours List, June, 1950 :—

C.B.E.

Professor O. G. Sutton, D.Sc., F.R.S.

BOOK RECEIVED

A revised analysis of solar-constant values, by C. G. Abbot. *Smithson. misc. Coll.,* **107**, No. 10. Size : 9½ in. × 6¼ in., pp. 9. *Illus.* Smithsonian Institution, Washington D.C. 1947.

WEATHER OF MAY 1950

Mean pressure was about 1020 mb. between Iceland and Norway, and over 1020 mb. south-westward of Vancouver Island. It was below 1010 mb. over most of Alaska, over Mexico and Arizona and in the Sahara. Deviations from the normal for May were generally small, but from southern Greenland eastwards to about longitude 0°, pressure was more than 5 mb. above normal, and it was above normal over an area extending from the eastern parts of the United States and Canada, across Greenland and the northern part of the North Atlantic to most of Europe and the central part of the Mediterranean.

In the British Isles the weather was very changeable with alternating cold and warm periods. It was dry on the whole but rainfall exceeded the average over much of an area extending south-east from the Wash to West Hampshire and locally in Devon and Cornwall.

During the opening days a large depression westward of Scotland moved north-east and turned east and became less deep; rain occurred generally on the 1st and showers and local thunderstorms on the 2nd. Thereafter, the Azores anticyclone spread north-east and mainly fair weather prevailed apart from slight showers locally in eastern districts of England on the 3rd and very slight scattered rainfall on the 4th. Subsequently a belt of high pressure extended south-south-west across the British Isles from an anticyclone over Scandinavia. Meanwhile a shallow depression moved slowly westward from Germany over England giving rain in England and Wales. On the 8th a small depression over Holland moved west-south-west and was associated with further rain in the southern half of England.

Thereafter, the Scandinavian anticyclone moved slowly south-west to a position off the north of Scotland and a spell of warm, sunny weather prevailed over the British Isles. Day temperatures reached or exceeded 70°F. at a number of places, among the highest readings being 76°F. at Prestwick on the 11th, 78°F. at Prestwick and 76°F. at Eskdalemuir on the 12th and 77°F. at Valentia on the 13th. On the 13th a new anticyclone near Iceland moved slowly east and later south-east and the dry spell persisted over the British Isles until the 16th, but a rapid fall in temperature occurred on the 14th, with an influx of cold northerly winds of polar origin. On the 16th and 17th a cold front moved slowly south over Scotland and Ireland giving scattered rain or showers in these areas but weather continued dry over practically the whole of England.

A change of type occurred on the 19th when a small depression developed to the west of Portugal and subsequently moved quickly north-east across England to the North Sea. Rain occurred fairly generally and there were local thunderstorms. By the 21st pressure was high from south-west Iceland to Norway and a large depression was centred off south-west Ireland, while associated troughs of low pressure moved north over the British Isles. Heavy rain occurred in places and was accompanied locally by thunder and hail (2·21 in. at Hockliffe, Bedfordshire, and 2·10 in. at Battlesden Pumping Station, Bedfordshire). In Buckinghamshire a tornado moving from Wendover to Linslade caused great damage. Trees were felled and vehicles in farmyards and tiled roofs of old buildings were lifted. There was also heavy rain and flooding and large hailstones; the largest individual stone, an irregular mass of ice with several centres, measured 6½ in. round. Subsequently, the depression off south-west Ireland drifted slowly south-west, while the anticyclone west of Iceland moved south and by the 24th the cold north to north-east winds over Scotland reached the south of England. From the 22nd to the 23rd rain occurred, chiefly in the south-west, and was heavy in places. On the 24th and 25th the depression, now centred north-west of Portugal, moved slowly east and later moved north-east to north France; further rain occurred in England, particularly in the south (1·97 in. at Torquay and 1·57 in. at Guernsey). On the 26th and 27th a depression centred over the south of Iceland moved south-east to the North Sea and on the 28th and 29th another disturbance over south Iceland moved east-south-east. Meanwhile, the Azores anticyclone spread east. Rain, mainly slight, occurred in many places on the 26th and 27th and further rain fell in the west and north on the 28th and 29th. On the closing days anticyclonic conditions prevailed and temperature rose again reaching or exceeding 70°F. at a number of places in England.

The general character of the weather is shown by the following provisional figures :—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ..	81	27	+0·1	90	−2	93
Scotland	80	23	+0·6	66	−3	107
Northern Ireland ..	75	32	+0·9	54	−6	119

RAINFALL OF MAY 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ..	1·42	81	*Glam.*	Cardiff, Penylan ..	2·10	86
Kent	Folkestone, Cherry Gdn.	1·28	76	*Pemb.*	St. Ann's Head ..	1·39	69
,,	Edenbridge, Falconhurst	1·61	87	*Card.*	Aberystwyth	1·33	64
Sussex	Compton, Compton Ho.	1·45	65	*Radnor*	Tyrmynydd	1·73	50
,,	Worthing, Beach Ho.Pk.	1·06	64	*Mont.*	Lake Vyrnwy	1·73	54
Hants	Ventnor, Roy. Nat. Hos.	1·74	102	*Mer.*	Blaenau Festiniog ..	2·20	39
,,	Bournemouth	1·90	108	*Carn.*	Llandudno	·50	28
,,	Sherborne St. John ..	1·33	69	*Angl.*	Llanerchymedd ..	·74	31
Herts.	Royston, Therfield Rec.	2·40	124	*I. Man.*	Douglas, Borough Cem.	1·17	47
Bucks.	Slough, Upton	1·71	102	*Wigtown*	Port William, Monreith	1·77	75
Oxford	Oxford, Radcliffe ..	2·19	117	*Dumf.*	Dumfries, Crichton R.I.	1·98	72
N'hant.	Wellingboro', Swanspool	3·16	163	,,	Eskdalemuir Obsy. ..	2·26	68
Essex	Shoeburyness	2·03	156	*Roxb.*	Kelso, Floors	1·19	62
,,	Dovercourt	1·40	101	*Peebles*	Stobo Castle	1·82	80
Suffolk	Lowestoft Sec. School ..	2·17	135	*Berwick*	Marchmont House ..	1·55	63
,,	Bury St. Ed., Westley H.	2·41	132	*E. Loth.*	North Berwick Res. ..	1·66	83
Norfolk	Sandringham Ho. Gdns.	2·14	117	*Midl'n.*	Edinburgh, Blackf'd. H.	1·89	92
Wilts.	Bishops Cannings ..	2·30	118	*Lanark*	Hamilton W. W., T'nhill	1·55	65
Dorset	Creech Grange.. ..	1·69	83	*Ayr*	Colmonell, Knockdolian	1·95	76
,,	Beaminster, East St. ..	1·55	75	,,	Glen Afton, Ayr San ..	1·82	61
Devon	Teignmouth, Den Gdns.	3·98	218	*Bute*	Rothesay, Ardencraig	1·44	48
,,	Cullompton	1·99	92	*Argyll*	L. Sunart, Glenborrodale	2·91	82
,,	Ilfracombe	1·52	74	,,	Poltalloch	1·91	66
,,	Okehampton, Uplands	3·08	115	,,	Inveraray Castle ..	2·52	64
Cornwall	Bude, School House ..	2·00	109	,,	Islay, Eallabus ..	2·75	104
,,	Penzance, Morrab Gdns.	2·35	106	,,	Tiree	1·26	50
,,	St. Austell	2·15	89	*Kinross*	Loch Leven Sluice ..	1·89	77
,,	Scilly, Tresco Abbey ..	2·31	137	*Fife*	Leuchars Airfield ..	1·91	98
Glos.	Cirencester	2·78	135	*Perth*	Loch Dhu	2·53	56
Salop.	Church Stretton ..	1·43	56	,,	Crieff, Strathearn Hyd.	1·46	59
,,	Cheswardine Hall ..	1·27	57	,,	Pitlochry, Fincastle ..	1·49	70
Worcs.	Malvern, Free Library	2·19	101	*Angus*	Montrose, Sunnyside ..	1·31	64
Warwick	Birmingham, Edgbaston	1·61	75	*Aberd.*	Braemar	1·43	60
Leics.	Thornton Reservoir ..	1·85	92	,,	Dyce, Craibstone ..	1·44	56
Lincs.	Boston, Skirbeck ..	3·36	191	,,	Fyvie Castle	1·62	63
,,	Skegness, Marine Gdns.			*Moray*	Gordon Castle	·83	39
Notts.	Mansfield, Carr Bank ..	1·67	79	*Nairn*	Nairn, Achareidh ..	2·17	122
Derby	Buxton, Terrace Slopes	1·56	50	*Inverness*	Loch Ness, Garthbeg ..	1·33	53
Ches.	Bidston Observatory ..	·72	38	,,	Glenquoich	3·79	69
Lancs.	Manchester, Whit. Park	1·46	69	,,	Fort William, Teviot ..	2·87	73
,,	Stonyhurst College ..	1·52	53	,,	Skye, Duntuilm ..	1·96	69
,,	Squires Gate	·93	45	*R. & C.*	Tain, Tarlogie House ..	1·82	88
Yorks.	Wakefield, Clarence Pk.	2·13	108	,,	Inverbroom, Glackour..	1·35	45
,,	Hull, Pearson Park ..	2·29	119	,,	Applecross Gardens ..	1·57	49
,,	Felixkirk, Mt. St. John	1·10	58	,,	Achnashellach	2·06	49
,,	York Museum	1·69	85	,,	Stornoway Airfield ..	·98	40
,,	Scarborough	1·62	85	*Suth.*	Loch More, Achfary ..	3·47	79
,,	Middlesbrough.. ..	1·40	73	*Caith.*	Wick Airfield	1·72	35
,,	Baldersdale, Hury Res.	2·09	81	*Shetland*	Lerwick Observatory ..	1·40	67
Norl'd.	Newcastle, Leazes Pk. ..	1·81	91	*Ferm.*	Crom Castle	1·18	42
,,	Bellingham, High Green	1·44	60	*Armagh*	Armagh Observatory ..		
,,	Lilburn Tower Gdns. ..	1·79	78	*Down*	Seaforde	1·14	43
Cumb.	Geltsdale	2·31	89	*Antrim*	Aldergrove Airfield ..	1·22	54
,,	Keswick, High Hill ..	2·24	70	,,	Ballymena, Harryville..	1·92	69
,,	Ravenglass, The Grove	1·62	58	*L'derry*	Garvagh, Moneydig ..	1·50	59
Mon.	Abergavenny, Larchfield	2·28	85	,,	Londonderry, Creggan	1·64	63
Glam.	Ystalyfera, Wern House	2·29	66	*Tyrone*	Omagh, Edenfel ..	1·32	51

M.O. 533 AIR MINISTRY

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METHOD OF FORECASTING THE TEMPERATURE OF FOG FORMATION

By W. E. SAUNDERS, B.Sc.

This investigation was intended to establish whether the dew-point curve of the radio-sonde ascent at 1500 G.M.T. could be used for selecting a surface temperature at which fog would form. It was known that forecasters had met with some success in fog forecasting by the use of the dew-point curve. Published work relating to the subject seems confined to that of W. C. Swinbank[1]*, who used the lapse rate of mixing ratio (hydrolapse) as one variable in a diagram for deciding whether fog was likely.

It was found that the dew-point curve could be used for this purpose. A comparison showed that fog developed at neighbouring stations at approximately the same temperature at each station. Occasions of no fog were generally those on which the estimated fog temperature was not reached.

Investigation of the controlling parameters.—Fog point is the surface temperature (T_f) at which fog forms. The intention was to find at what height (z)† on the 1500 dew-point curve the potential dew point was the fog point (*i.e.* at what height the constant-mixing-ratio line through T_f intersected the dew-point curve).

It was noted that this level was often very close to the afternoon condensation level of the air at screen level. Since the height (z_1) of this latter level corresponding to any given values of the surface dry-bulb and dew-point temperature is proportional to their difference it appeared that this difference might be a significant parameter.

To test this, 48 cases of fog at Northolt in which there was a representative tephigram available were examined. This represented 63 per cent. of the total occasions of freshly formed water fog in the period August 1948 to November 1949. To restrict the investigation to water fog the criteria visibility of 1,000 yd. or below, and relative humidity 95 per cent. or more, were adopted. The temperature at which fog formed, or at which there was a transition from smoke fog to water fog as defined above, was taken from the hourly or half-hourly temperature readings. The height z was read for each fog point from the representative tephigram for 1500, on which dry-bulb and dew-point temperatures were plotted.

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*The index numbers refer to the list of references on p. 219.

†For convenience in working on tephigrams, height (z) is expressed in equivalent pressure difference (mb.).

For each occasion $(T-T_d)$ was plotted against z (T and T_d were the surface dry-bulb and dew-point temperatures on the 1500 ascent). The curve for z_1 (almost a straight line) was also plotted. For small values of $(T-T_d)$ the curves for z and z_1 were almost identical. With increasing height the curve for z gradually diverged from that for z_1 in the direction of increasing $(T-T_d)$.

It appeared that a closer relation would be likely if some correction were applied which had the effect of making a small reduction in the numerical value of $(T-T_d)$. A corrected surface temperature (T_c) was then substituted for T. T_c was the surface temperature given by following the dry adiabatic of the lowest potential temperature in the layer affected by diurnal heating to the surface pressure. T_c effectively ignores superadiabatic layers near the surface, and must correspond very closely with the theoretical maximum temperature derived by E. Gold[2]. The writer found it necessary to apply a similar correction in earlier work on cooling[3]. For purposes connected with the afternoon tephigram T_c appears appreciably more significant than the actual maximum temperature.

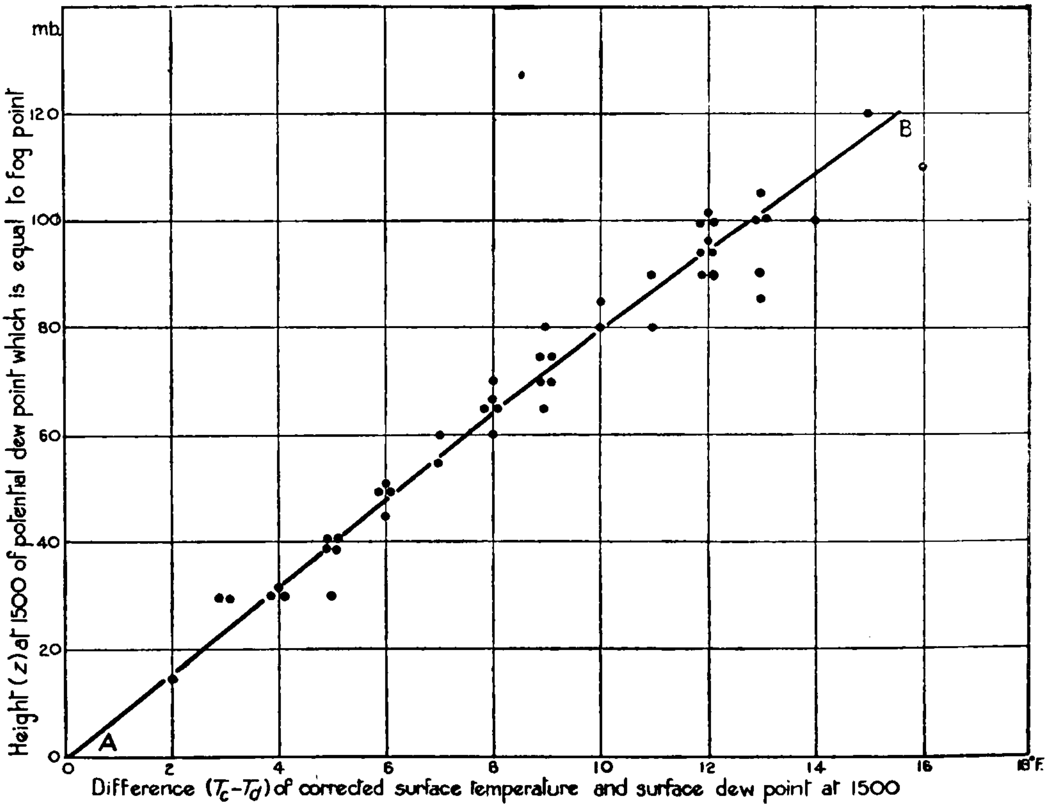


FIG. 1—VARIATION OF HEIGHT OF POTENTIAL DEW POINT WHICH IS EQUAL TO FOG POINT WITH DIFFERENCE BETWEEN CORRECTED SURFACE TEMPERATURE AND SURFACE DEW POINT AT 1500 G.M.T.

Line AB represents the height (z_1) of the intersection of the dry adiabatic T_c and constant-mixing-ratio line through T_d corresponding to values of (T_c-T_d)

The results of plotting $(T_c - T_d)$ instead of $(T - T_d)$ against z are given in Fig. 1 by the dots. AB is the line giving the heights z_1 of the intersection of the dry adiabatic through T_c and the moisture isopleth through T_d corresponding to the values of $(T_c - T_d)$ along the abscissa; it is not the mean of individual values of z. It is seen, however, that AB is practically identical with the mean of the plotted values of z. Hence, for practical purposes, $z = z_1$, and T_f is the potential dew point at the level of the intersection of the dry adiabatic through T_c and the constant mixing ratio line through T_d. The mean curve for z may still diverge a little from that for z_1 above a value 12°F. of $(T_c - T_d)$. The number of cases in this region is too small to warrant a definite conclusion on this.

The result suggests that the depression of fog point below the afternoon dew point is proportional to the lapse rate of potential dew point with height, and approximately proportional to the depression of dew point below the temperature at the time of maximum temperature. It is of course probable that other parameters, such as state of ground, which it has not been found necessary to take explicitly into account, are in fact contributory in setting up the 1500 dew-point curve, and so influence the result.

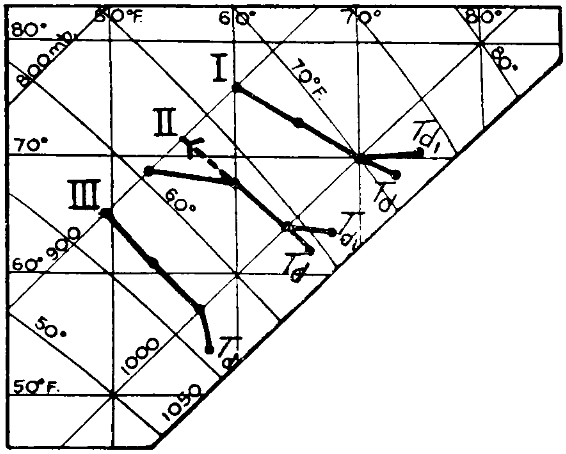


FIG. 2—DEW-POINT CURVES AT 1500 G.M.T.

The dew-point curve at 1500.—Fig. 2 gives the three significant types of dew-point curve which were encountered in the work described in the previous section.

Type I.—As a result of heating and turbulence, moisture has become distributed to give constant hydrolapse. The surface value of the dew point may be in alignment with the higher values (T_d), or may be displaced a little to the right (T_{d_1}) in harmony with a superadiabatic lapse rate of the dry bulb.

Type II.—The hydrolapse increases above some point within the layer concerning us. This may occur when marked subsidence extends down to this level, or where two air streams of different origin are involved, such as a dry continental stream flowing over a moister south-south-west current over southern England. To obtain a result consistent with that obtained for Type I dew point, the portion of the dew-point curve unaffected by mixing with the drier air had to be produced upwards in its own direction, and the potential dew point taken along this corrected dew-point curve.

Type III.—The dew-point lapse rate in the lowest layer is less than that prevailing above. This case may be subdivided as follows:—

Type IIIA.—The dry bulb fails to attain the dry-adiabatic lapse, or by 1500 the dry bulb has fallen slightly below a dry-adiabatic lapse previously attained, and the dew point has fallen with it. These cases are dealt with as for Type I.

Type IIIB.—This dew-point distribution is occasionally found even with dry-adiabatic lapse reached or exceeded by the dry bulb, when turbulence is exceptionally slight during the afternoon. This is characterised by very small values of the wind shear from the ground to 900 or 850 mb. In these cases it appears that surface moisture does not become completely mixed, and the afternoon dew point is itself the fog point. On several successive days during the last week of August, 1949, the synoptic situation was exceptionally stagnant. On one occasion the wind speed was only 2 kt. to 850 mb. at Larkhill. Visibilities of the order 2–3 miles reported during the afternoons over southern England might, having regard to the time of year, be taken to indicate that haze, as well as moisture, was not being freely mixed. Thick night fogs occurred, with little or no depression of dew point from afternoon values.

Some tests of the result obtained.—For the occasions which were used in the preparation of Fig. 1, the actual fog temperatures at Northolt (which were usually obtained without difficulty within one degree from the half-hourly temperature readings) were plotted against the estimated T_f derived from AB of Fig. 1. For nights of clear sky and light wind when no fog formed the minimum temperature was plotted against the estimated T_f. The results, given in Fig. 3, show that when fog formed, given a representative tephigram, the temperature of fog formation would have been forecast within one degree on 44 occasions out of 48. Of 18 occasions of no fog, the estimated T_f would have been reached four times. These were occasions of ground fog but not general fog.

Fig. 3 suggests that the absolute value of T_f makes little difference to the result, at any rate over the range 25° to 60°F.

The results of a comparison between estimated and actual fog temperatures at neighbouring airfields for those occasions during the period August 1948 to May 1949 when a representative sounding was available are given in Table I.

TABLE I—COMPARISON AT STATIONS IN AREA WEST OF LONDON

Station	Occasions when fog formed		Occasions (light wind and clear sky) of no fog	
	Actual T_f within ± 1°F. of estimated T_f	Actual T_f differed from estimated by more than ± 1°F.	Estimated T_f not reached	Estimated T_f reached
	number of occasions			
South Farnborough	21	2	18	3
London Airport	25	2	20	1
Hendon*	17	2	21	1
Bovingdon	18	3	19	1

*Station closed at some periods

Within the +1° limit there appeared a tendency for fog to develop at +1° at London Airport, and at −1° at South Farnborough.

Mr. E. T. Baker tested the method at Hemswell and Waddington on eleven nights in September to November 1949. There were six fog occasions. In four of these water fog appeared to form at within ±1° of the estimated T_f. In two cases fog formed at a temperature several degrees higher than T_f estimated from the Downham Market sounding, but it was afterwards noted that there had been advection of moister air from the south in both cases. In the first Larkhill would have given an exact result, while in the second a sounding made intermediately between Larkhill and Downham Market would have served. On each of five potentially foggy nights during which no fog formed the night minimum temperature was above the estimated T_f.

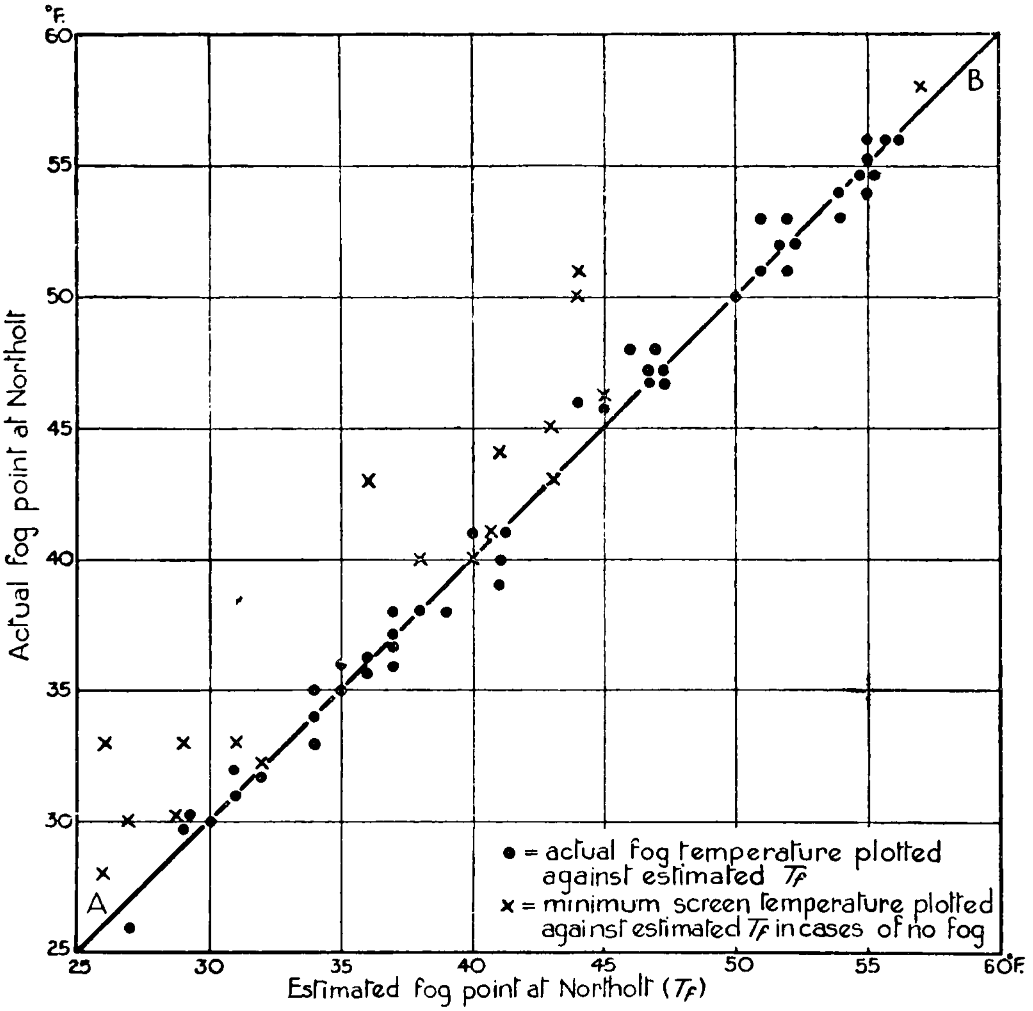
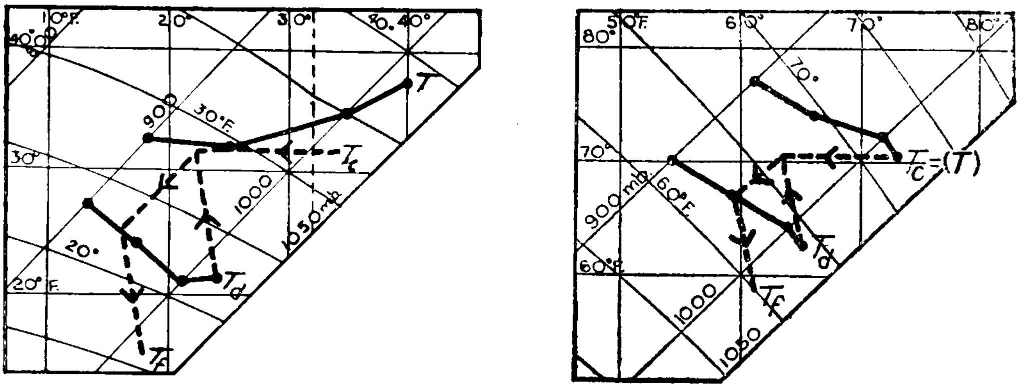


FIG. 3—COMPARISON OF ESTIMATED AND ACTUAL FOG TEMPERATURES

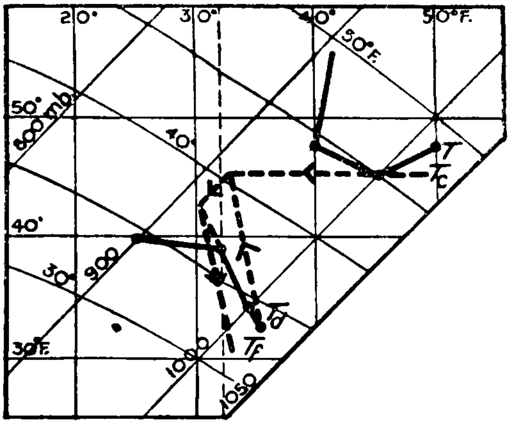
AB is the line of least error in actual Fog cases

Suggested forecasting procedure.—(*a*) *Use of the tephigram.*—In Fig. 4 full lines indicate the dry-bulb and dew-point curves on the 1500 tephigram, and broken lines the construction for T_f. In Type II the drying out often appears to work down to below the inversion. If any depth of moist air remains at 1500 T_f must be derived from extension of the dew-point curve in the moist air.

Cases were noted where dry air penetrated down to only 20 or 30 mb. above the ground at 1500, yet T_f was clearly the value corresponding to the moist air at all stations. In such extreme cases, to use so shallow a layer from a routine sounding would obviously invite error, and it is better to use the surface dew point as T_f. Type IIIA calls for no comment. Type IIIB is the special case referred to on p. 216, where the surface dew point is the fog point.



(a) Type I (b) Type IIIA



(c) Type II

FIG. 4—SUGGESTED USE OF THE TEPHIGRAM

(*b*) *Representative tephigrams.*—The question of whether a particular sounding is representative has to be determined from the synoptic situation with special regard to the wind direction and speed. An ascent up-wind in the same air mass is generally representative, but possible advective changes have always to be looked for and allowed for. With no ascent up-wind, a sounding elsewhere in the same airstream may be satisfactory if the surface dew points are within one degree. The advection of moist sea air presents a special problem: T_f will be higher in air which has been advected from the sea than in air which has been heated over the land, and the tephigram in the sea air must usually be estimated. In a few cases the afternooon sounding is rendered non-representative by rain preceding fog.

(*c*) *The case of T_f below freezing.*—For the area considered, and for the range 25–32°F., the results suggest that when T_f is reached thin fog forms with visibility of the order 600–1,000 yd., provided there is not also thick smoke.

(*d*) *Ground and adjacent fog; delayed fog.*—Owing to irregular cooling, ground fog or adjacent fog, with visibilities 1,000–2,000 yd., is often reported with the screen temperature still several degrees above T_f. Occasionally T_f is reached and fog formation delayed for several hours, perhaps owing to lack of turbulence. The period after sunrise will obviously be critical if T_f has been reached without fog forming.

(*e*) *Smoke fog.*—Smoke fog depends upon the parameters wind direction and speed, vertical temperature gradient, time of day, day of week and season of year, and can exist with relative humidity as low as 60–70 per cent. Consequently smoke fog cannot be dealt with by a numerical addition to T_f, and it must be dealt with separately.

(*f*) *Stratus cloud.*—If turbulence is sufficient to cause stratus cloud to develop at height z_2, instead of fog, it should be possible to forecast the surface temperature (T_s) at which stratus will form by drawing the constant-mixing-ratio line through T_f to this height. The dry adiabatic intersecting this mixing-ratio line at height z_2 should then reach the surface at T_s. This method has given satisfactory results in some cases, and appears worthy of further trial.

Acknowledgment.—The writer is indebted to Dr. R. C. Sutcliffe, at whose suggestion the work was undertaken, and to Mr. G. A. Corby and Mr. J. M. Craddock, for discussions and suggestions at various stages, and to Mr. E. T. Baker for testing the method in Lincolnshire. The forecasting staff at Northolt have been most helpful in testing the method.

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CAMBRIDGE UNIVERSITY ICELAND EXPEDITION OF 1947

Meteorology

By D. S. BROCK, B.A.

The Cambridge Iceland Expedition 1947, led by I. R. Menzies, went to the north-west peninsula of Iceland to undertake glaciological and entomological work on the south-west margin of the Drangajökull ice-cap. Meteorological observations were maintained for the period from August 5 to September 5, 1947, at the Base Camp approx. 66°5′N. 22°10′W. The Stevenson screen was erected on a low heap of moraine some 200 yd. (180 m.) from the Camp at an altitude of 1,125 ft. (343 m.) above sea level. Observations were taken throughout the period at 1000, 1400, 1800 and 2200 G.M.T. Pressure was read from a pocket aneroid at the Base Camp at the same periods: weight prevented the inclusion of a barograph. Records were made of the daily maxima and minima, wet- and dry-bulb temperatures, the direction and strength of the wind, the amount and type of cloud cover, and the amount of precipitation.

The Base Camp station lay in a wide north-south valley with gently sloping sides, rising to 2,140 ft. (652 m.) on the west and 1,370 ft. (418 m.) on the east. To the south the gentle slope extended for three-quarters of a mile (1,200 m.) before plunging down to the south-westerly flowing Selá. To the north-east lay the south-west corner of the Drangajökull ice-cap at a distance of 2½ miles (4 Km.), rising to a crest of 2,788 ft. (850 m.) with an average gradient of 1 in 11.

The month was characterised by the passage of a number of depressions moving north-eastward up the Denmark Strait taking an average of four days to travel from Cape Farewell to north of Scoresby Sound. The average cloud cover during daylight hours for the month was 8 tenths and owing to the persistence of low cloud the direction of upper winds could only be obtained on very few occasions; on all but two of these the direction coincided with that of the surface winds measured at the station. It is considered, therefore, that the lie of the wide and shallow valley had little effect on the local winds at 1,125 ft. (343 m.) which generally crossed it at an angle. The farmers on the fjord coast to the south-west of the ice-cap usually relied on the NE. winds off the ice-cap to bring them clear fine conditions for their hay harvest, but the summer of 1947 was a particularly poor one for Iceland and, in the north-west peninsula, there was a greater proportion of rain-bearing SW. winds than NE. winds in the month that observations were taken. The depressions tended to travel slowly up the Denmark Strait, in some cases remaining several days to the west of Iceland, only to be rapidly replaced by further depressions as soon as they had passed to the north. Their presence accounted for a greater preponderance of SW. winds than is usually met with in the Icelandic summer.

Winds from the south-west and south-south-west prevailed for nearly three times as long as those from the north-east. These SW. winds tended to be stronger in character than those from other directions. The winds were invariably stronger during the daytime than during the night. In the thirty days from August 6 to September 4, there were only four occasions on which the average wind speed for the twelve hours 2200–1000 was greater than that for the period 1000–2200. The steadiness of the wind on certain days was particularly noticeable: from 2200 on August 16 to 2200 on August 17 the 24-hr. average was 22·9 m.p.h. (37 Km./hr.). The highest recorded wind speed over a one-minute interval (at 1400 during this period) was 33 m.p.h. (53 Km./hr.), whilst the highest 4-hr. average (from 1400–1800) was 26·5 m.p.h. (42·5 Km./hr.).

The two highest temperatures, 63·5°F. (17·5°C.) on August 22 and 62·5°F. (17°C.) on August 26, were associated with the passage of warm fronts from south to north and with southerly winds. The lowest temperature, 36·5°F. (2·5°C.) on the night of August 19–20 was associated with the presence of a depression on the east coast of Greenland to the west of Iceland and with the cool SW. winds of polar origin associated with it. The average minimum temperature at 1,125 ft. (343 m.) between 2200 and 1000 was 43·1°F. (6·1°C.): there is evidence to show that, even in August, the temperatures in the bottoms of the valleys are considerably lower than this. On nights with still air and clear skies, frost was observed in the valleys. Although the mean daily temperature fluctuates considerably over the period there does not appear to be any consistent rise or fall during the month.

The total rainfall for the month was 1·67 in. (42·46 mm.), 90 per cent. of which fell in the first half of the period. The days where no rainfall is recorded were often overcast with a steady drizzle throughout the daylight hours which was not recorded in the rain-gauge. Twelve days are recorded without rain, but on only five of these did the sun shine for any considerable time. On the night of August 18 snow was experienced on the ice-cap at 2,800 ft. (854 m.) with a SW. wind of estimated speed 50 m.p.h. (80 Km./hr.); the temperature at 1,125 ft. (343 m.) at this time was 37·5°F. (3·1°C.) and the average wind speed during the night was 21 m.p.h. (34 Km./hr.).

TABLE I—PERCENTAGES OF OBSERVED CLOUD TYPES DURING DAYLIGHT HOURS FOR THE MONTH AUGUST 5 TO SEPTEMBER 5, 1947

Cloud type	Over the Base Camp and fjords	Over Drangajökull
	per cent.	
Stratocumulus	25·6	10·4
Cumulus	24·8	22·4
Stratus	16·0	45·6
Altostratus	14·0	6·4
Nimbostratus	8·8	8·0
Altocumulus	5·2	0·8
Cirrocumulus	1·6	0·8
Cirrus	1·6	2·4
Cumulonimbus	1·6	0·0
Cirrostratus	0·8	0·8
Nil	0·0	2·4

The above table shows the percentages of cloud types during daylight hours. The figures for Drangajökull illustrate those conditions that exist over the south-west side of the ice-cap. Conditions on either side would vary considerably as was evidenced by journeys over the ice-cap. With a NE. wind, clouds would pile up on to the eastern side of the ice-shed whilst the west side was clear. With a SW. wind the ice-cap tended to be covered on both sides but the cloud level on the eastern slopes was higher than that on the west. The amount of altostratus shown over the Base Camp is somewhat misleading as, in fact, whenever a break occurred in the stratocumulus a higher layer of altostratus was usually observed.

The figures for humidity do not show much more than an expected lowering during the warmer hours of the day. Only on one occasion did the relative humidity fall below 60 per cent. and the average was in the neighbourhood of 82 per cent.

On the southern half of Drangajökull in late August 1947 the firn line was found to extend down to 2,450 ft. (747 m.) on either side. The ice-shed, which in this portion runs north-west—south-east, lies 3½ miles (5·6 Km.) from the south-west edge of the ice and 2 miles (3·3 Km.) from the north-east edge. The average gradient of the south-west slope is 1 in 11 and that of the north-east slope is 1 in 7. It will be seen, therefore, that there is a greater accumulation of firn on the south-west slopes than on the north-east slopes, and this is confirmed by the presence of large drifts on the south-west sides of the nunataks. This accumulation is due to the predominance of NE. winds in the area. In recent years, depressions passing eastward across the Atlantic have tended to travel to the south of Iceland both in summer and in winter and the NE. winds resulting from them have struck the eastern flanks of Drangajökull. The sudden rise of 3,035 ft. (925 m.) accounts for the amount of orographic precipitation and the distribution of snow in considerable volume on the south-west flanks. Thirty-three miles (53 Km.) to the south-west of Drangajökull lies the summit of Gláma, which is the same height as Dranga and of similar area. At the beginning of the century this peak carried an ice-cap but now only has large permanent snow patches on its flanks. It is considered that the reason why Dranga still has an ice-cap and Gláma has not is that the former has received far greater winter precipitation than the latter, and that consequently an amelioration of the climate of the region will have had a proportionately greater effect on the speed of ablation of the Glámajökull compared with the Drangajökull.

The Expedition wish to express their thanks to Professor Gordon Manley, M.A., M.Sc., for his assistance and advice on many matters, and also to the Royal Meteorological Society, the Meteorological Office, Air Ministry, and the Vedurstofan Reykjavík for the loan of instruments.

OXFORD UNIVERSITY ICELAND EXPEDITION OF 1947

Meteorology

By C. SWITHINBANK

The expedition spent seven weeks in south-east Iceland, and was engaged mainly in botanical work. Meteorological instruments were lent by the Meteorological Office, Air Ministry. A continuous programme was carried out at a Base Camp near the south coast situated at approximately 63°55'N. 17°45'W., and a small party spent 38 days on the ice-cap Vatnajökull. At the Base Camp, observations were taken three times daily, at 0800, 1400, and 2100 G.M.T., from July 29 to September 8. The instruments used were maximum, minimum, and ordinary thermometers; and a hair hygrograph. Pressure was read simply from a pocket aneroid and rain was only roughly estimated. General weather conditions, visibility, and cloud cover (in tenths) were recorded. Wind direction and speed were estimated. In addition to the work at the Base Camp, a few scattered observations were taken on the ice-cap between July 31 and August 28. In this case the instruments used were wet- and dry-bulb thermometers, and a hand anemometer.

Observations at the Base Camp.—The Base Camp station was situated at the farm Kálfafell, on the edge of the coastal plain. The sea lay 15 miles to the south over a flat, low lying area. To the east and to the west a line of cliffs, from 300 to 2,100 ft. in height, rose abruptly from the plain. These were dissected by broad, deep valleys, running in a north-south direction. At the head of these valleys, 10 miles from Kálfafell and at an altitude of 1,900 ft. above sea level, was the edge of the ice-cap. The screen was set up in an exposed position at an altitude of 170 ft. above sea level.

During the period of observing, pressure usually fell towards the south-west. A number of depressions passed north-eastward up the Denmark Strait, and one, between September 4–6, passed immediately to the south of Iceland moving in the same direction. The weather at Kálfafell is certainly not determined solely by the influence of these depressions. Local influences continually interfere. For instance, it is probable that the high land to the north, together with the very extensive ice mass of Vatnajökull, frequently causes katabatic winds to disturb the cyclonic winds; that the temperature is affected by the North Atlantic Drift, which moves along this particular part of the coast; and that the rainfall is increased by the rapid rising of the land behind the coastal plain.

The percentage frequency of observed wind directions is shown in Fig. 1. It seems probable that the air stream passing over the station was often of no great depth, and that local topographical features accounted for some deflection.

Similarly, the high percentage of calms observed has no particular significance, since Kálfafell receives considerable protection from a steep slope immediately to the north. The preponderance of NE. and E. winds is contrary to the direction of the main air stream over Iceland. The average cloud cover was 8 tenths; no two consecutive observations recorded blue skies. On some occasions when winds were blowing in from the sea an orographic cloud formed immediately above a 2,100-ft. high cliff near the Base Camp, and remained stationary while the main cloud layer, at a considerably greater altitude, moved northward. On one such occasion rain was seen to be falling from the stationary cloud.

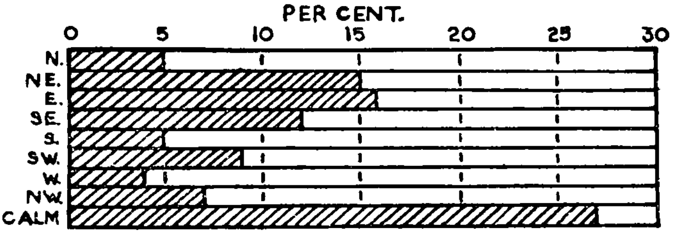

FIG. 1—PERCENTAGE FREQUENCIES OF SURFACE WIND AT BASE CAMP (APPROX. 63°55′N., 17°45′W.), JULY 29–SEPTEMBER 4, 1947

The mean of the temperature measurements at the daily times of observation over the period was 53·1°F., and the mean daily range of temperature was 9·7°F. The highest recorded temperature was 73·0°F. on August 3, this being associated with the passage of a warm front. The lowest recorded figure was 38·2°F. on the night of August 27–28. It appeared to be associated with a marked inversion of temperature, the night being one of the very few during which the air was still and the sky was cloudless. It is interesting to note that in spite of a katabatic movement of air down the valleys from the ice-cap which was quite common at night-time, and in spite of the favourable conditions for inversion which are found in the valleys themselves, no frosts were recorded at the Base Camp, neither were any signs of frost noted in the valleys. Katabatic winds were shallow, as was occasionally shown by the direction of movement of the cloud cover, and they were easily displaced by winds associated with the passage of depressions.

The narrow strip of land lying between the southern ice-caps and the sea is the wettest inhabited region of Iceland. The nearest observing station at Fagurhólsmýri, 32 miles to the east, has a mean annual rainfall of 74 in. July–August is the driest period of the year, and September–October is the wettest. During the period of observation at the Base Camp, 9·4 in. were recorded, rain falling on 28 out of 37 days. Most of the wet weather occurred when winds were blowing in from the sea, and took the form of prolonged showers or light continuous drizzle. The biggest downpour was on August 14, when 1·13 in. fell before 0800. The wind at the time was a moderate south-westerly.

Observations on Vatnajökull.—The weather on the ice-cap from July 31 to August 28 was predominantly mild and very wet. No single day was without both rain and thick fog. The winds were on the whole stronger than those recorded at the Base Camp. This was no doubt largely due to the relatively exposed position of the ice-cap stations. The records show that 65 per cent.

of the winds were northerly, a singularly high percentage in comparison with the frequencies at the Base Camp. It is possible that this is the result of a partly permanent outflow of cold air from the centre of Vatnajökull*, that same movement of air which gives rise to the katabatic flow down the valleys at night. No high wind speeds were recorded, the highest over any one-minute period being 25 m.p.h. on August 9.

The mean day temperature was 38°F., the mean daily range being small. The maximum temperature was 46°F. on August 11; the minimum was 30°F., slight frost being observed during several nights.

The total rainfall over the period was not recorded. Throughout several days and nights rain was practically continuous, and during others heavy and prolonged showers alternated with wet mists. A particularly bad spell of weather from August 8–10 brought persistent winds of force 5 and a total of 5·0 in. of rain.

As a result of the practically continuous fog on the ice-cap, no estimation of cloud cover could be made. During approximately 9 tenths of the period the visibility was less than 120 yd. On the few occasions when the clouds lifted, visibility was excellent under the influence of a fresh northerly breeze. Relative humidity was consistently high, the average at the times when observations were made being 93 per cent.

The records show that at both Base Camp and ice-cap stations the weather did not depart widely from the normal for the time of year. The only exception was the rainfall, which must have been considerably above average at the Base Camp (as it was at Fagurhólsmýri), and which on Vatnajökull, had continuous records been made, might well have proved to be exceptional.

SNOWSTORM DURING THE NIGHT OF APRIL 25–26, 1950

Heavy snow, accompanied by strong winds, occurred widely south of the Thames, during the early morning of April 26, damaging trees and causing considerable disruption of traffic and telephone services. The amounts of undrifted snow reached or exceeded 6 in. in depth at 0700 (all times are G.M.T.) over a narrow belt extending roughly from Faversham (Kent) to Salisbury, as shown in Fig. 1. A rainfall map for the 24 hours ending at 0900 on April 26 is also given, as Fig. 2, and this shows that there was a good deal of rain in addition to the snow.

The weight of the wet snow, which tended to stick, together with the wind, caused destruction to trees, shrubs, telephone poles, *etc.* The wind was northerly. In north-east Hampshire it was noted by Mr. Poulter that telegraph wires set in the direction of the wind were not much affected, whereas the damage occurred where they were at right angles to the wind, *i.e.* from west to east. The wind reached gale force at times. Details of the times and directions of the highest gusts at anemograph stations in the district are set out in Table I.

TABLE I—HIGHEST GUSTS RECORDED AT ANEMOGRAPH STATIONS ON THE NIGHT OF APRIL 25–26, 1950

Station	Highest gust		Time
	°true	kt.	G.M.T.
Manston	170	30	0200
Croydon	90	28	0050
Calshot	350	53	0315
Boscombe Down	340	39	0300

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*Large areas of which are at an altitude of over 4,000 ft. The mean altitude of the observing stations was 3,000 ft.

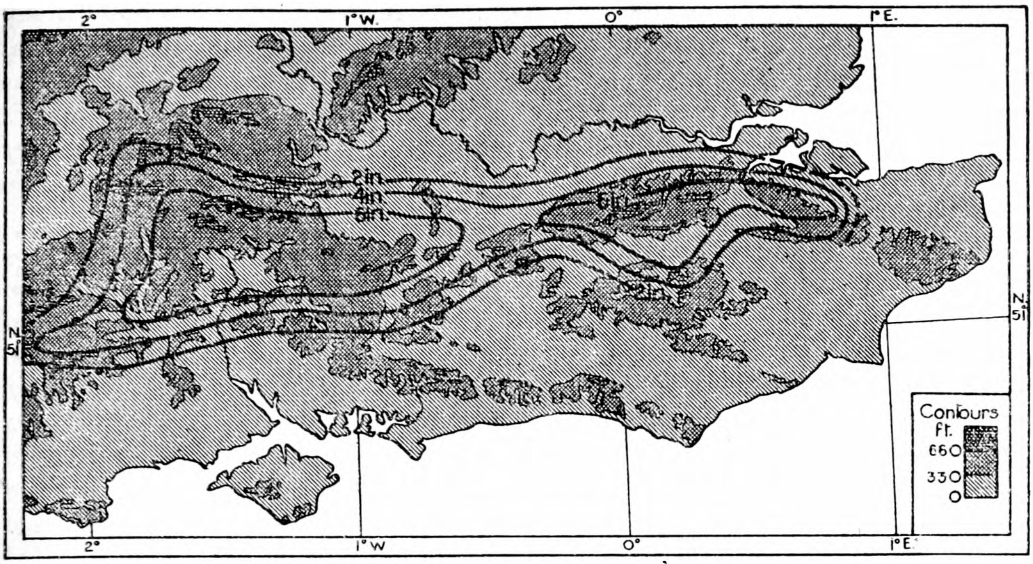

2°
1°W.
0°
1°E.
2in
4in
6in
6in
2in
N.
51
Contours
ft.
660
330
0

FIG. 1—SNOW DEPTH IN INCHES ABOUT 0700 G.M.T., APRIL 26, 1950

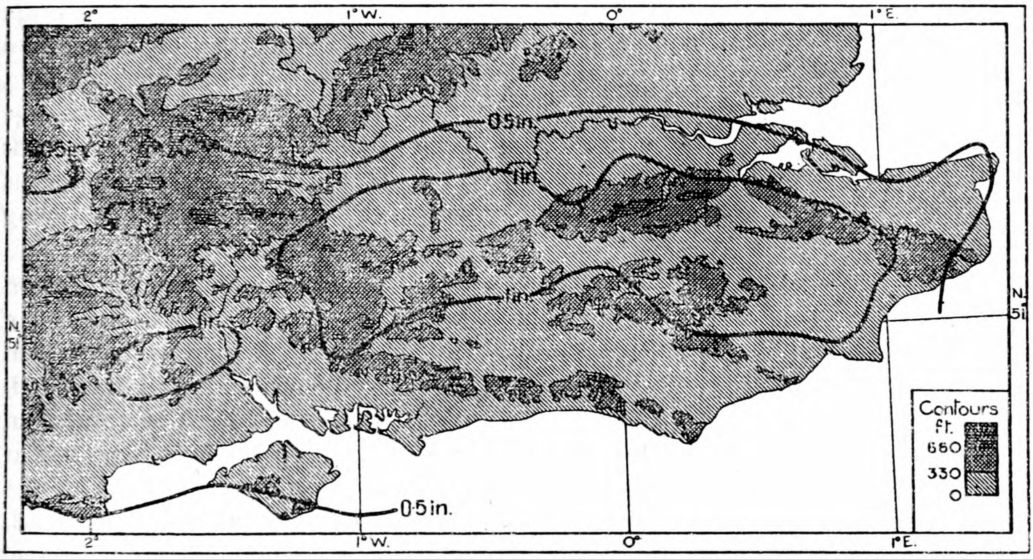

2°
1°W.
0°
1°E.
0·5in.
1in.
1in.
0·5in.
N.
51
Contours
ft.
660
330
0

FIG. 2—RAINFALL IN INCHES, 0900 G.M.T., APRIL 26, 1950

Two photographs are reproduced by courtesy of Mr. R. M. Poulter (see photographs between pp. 228-9) showing (*a*) telegraph wires sagging under the weight of snow at South Farnborough and (*b*) a large branch newly severed from a tree at Aldershot. The latter was taken at 1130 when much of the snow had disappeared from the trees. Other photographs contributed by Brigadier R. E. Fryer show (*c*) a French Bristol Freighter at Blackbushe Civil Airport—the photograph was taken at about 0900—the two Frenchmen are brushing 6 in. of snow off the wings preparatory to taking off; (*d*) the Brigadier's garden near Camberley at about 0700, with the thick coating of snow on the sagging telegraph wires and on the trunks of the trees and the vertical surfaces of wire netting, as well as on all horizontal surfaces. He says:—" the level depth of the snow in my garden was 5½ in. The wind was north and the snow stuck easily to the vertical sides of the chimneys on the north side. The damage to trees in our area was very great, the chief sufferers being silver birch and poplars. . . . In the grounds of the Staff College large beech trees probably 18 in. or more in diameter crashed." The last photograph shows the thickness of the snow on the north side of a small tree.

The Observer at Farnham (Boundstone), Mr. Hampton Brown, writes:—" Hundreds of trees were brought down or else dropped major branches from the weight of snow. Telegraph poles and wires were dragged down or snapped off, trains and buses stopped and in some parts electric light failed." From Farnham (Rowledge), Mr. D. M. Gordon says:—" The snow-storm . . . caused great damage to trees and shrubs . . . Brooms suffered severely. In this area there appeared to be an unbroken sheet of snow up to Dockenfield (3 miles to the south) as the trees and hedges were coated to their tops and minor bushes and plants pressed down flat." At Amesbury (Boscombe Down) the snow blocked the opening to the pressure tube of the Dines anemograph, making the record defective, and just after 0200 the Meteorological Officer climbed the mast in a strong wind to clear it.

The following is an extract from a notice sent to subscribers on May 6 by the Telephone Manager, G.P.O., Guildford:—" The full extent of the interruption to the telephone system, caused by the snowstorm of April 26, has now been assessed, and it is clear that the damage is heavier than was at first thought. No part of the Guildford Telephone Area has escaped and over 11,000 exchange lines (about one-third of the system) have been affected. The damage exceeds anything that has ever been experienced in these parts before, and presents a state of emergency comparable with the worst effects of enemy action during the war."

The heavy snowfall was the culmination of two wintry days resulting from an outbreak of arctic air from a very high latitude, following a track to the east of Greenland and then directly over the British Isles. A depression which developed to the north of Iceland on the 22nd moved south-east and deepened. On the morning of the 24th it was centred over the western North Sea and then it performed a circuit to the left. Fig. 3 shows its position off East Scotland at midnight on 25th–26th, and also its curved track from the morning of the 25th till the evening of the 26th, when it filled up near Flamborough Head. The figures in brackets are the central pressures at the times indicated. Snow fell widely on the 24th and 25th, including the south-eastern districts, where there was appreciable snow lying on the morning of the 25th, though it quickly melted. When the much heavier fall occurred on the following night the supply of cold air had already been cut off and the temperatures over Scotland at midnight (Fig. 3) were 10°F. or more higher than those of 24 hours earlier, the rise being as much as 14°F. at Dyce and 13°F. at Lerwick.

The heavy snowfall was due to the depression shown in the English Channel in Fig. 3, which also indicates the track of centre and the central pressure at various times. It existed in an incipient form over Central Ireland at 1200 on the 25th, moving south-east as a small secondary disturbance, developing a closed isobar at 1500 near the south-east Irish coast, and then turning eastward into the English Channel and later moving north-east as shown. At midnight it was raining in the London area but soon afterwards this turned to wet snow.

At midnight the wet-bulb temperature at London Airport was 36°, and the subsequent fall to near freezing point in the same air mass as the rain turned to snow may be attributed to snow falling into the layer. Most of it fell within six hours. In the Midland area there was a calm fair patch with keen frost.

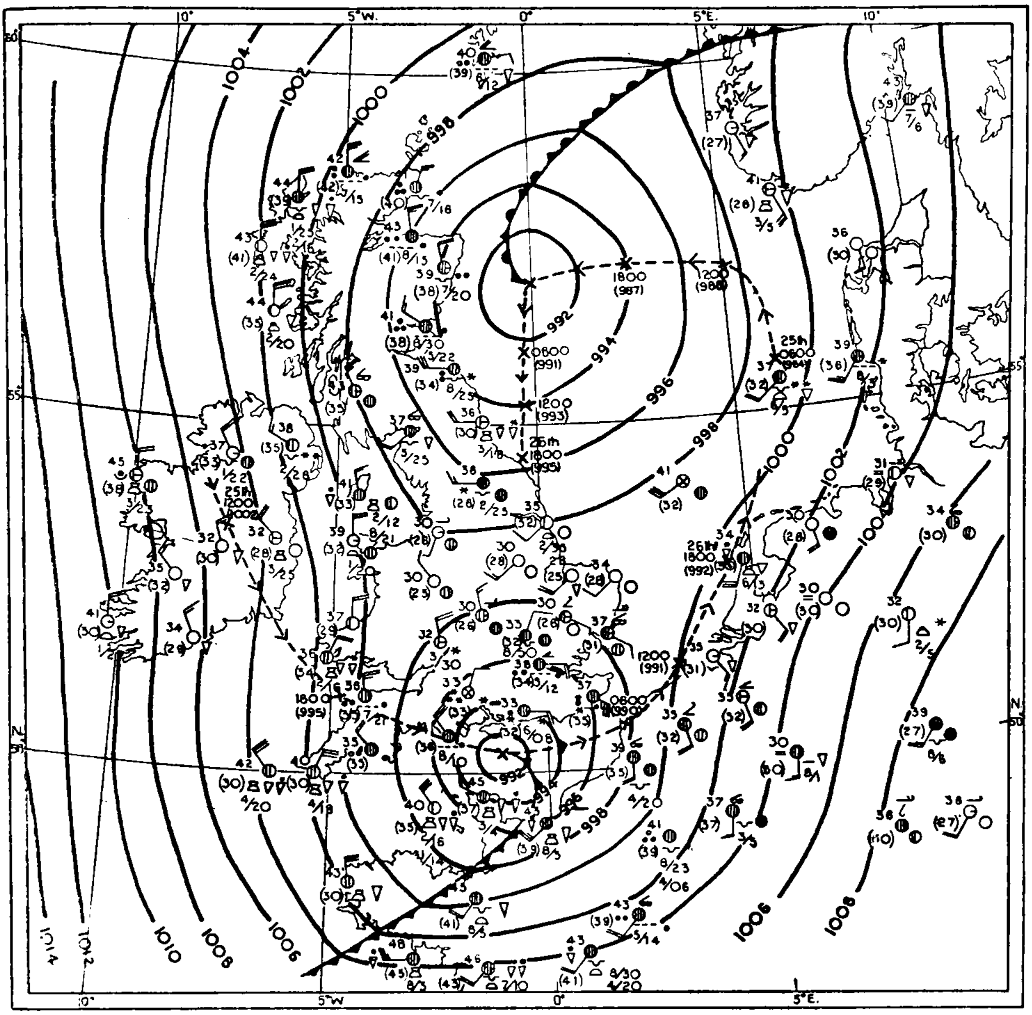


FIG. 3—SEA-LEVEL SYNOPTIC CHART, 0001 G.M.T., APRIL 26, 1950
Depression tracks are indicated by broken lines
Figures in brackets are the central pressures in mb. at the times indicated

As in the case of the severe April snowstorms of 1908, 1917, and 1919, and various other spring and winter snowstorms, the associated depression developed in polar air, forming in a region of steep horizontal temperature gradient although there was no definite pre-existing front. The cold front shown on the chart developed over Ireland simultaneously with the depression and swung round it. There was no definite warm front, but a diffuse frontal zone shown by temperature and dew point. On the previous evening at 1800 the dew point was 45° at Lizard and 44° at Scilly. When a cold front advances through a zone of this type it may assume the structure of an occlusion, but there are no definite criteria either for putting in a warm front in the diffuse zone or for turning the cold front into an occlusion. In this case the front resembled an occlusion close to the centre of the depression but it would be an unnecessary complication to alter the name of this portion of it.

In the case of warm-sector depressions and some occluded depressions the maximum rainfall to the left of the track can be explained mainly in terms of duration, but unless the air in the warm sector is already saturated in a thick layer extending well above freezing level the maximum rainfall is likely to be at an appreciable distance from the sea-level front, falling through the cold air. In the present case there was no clearly discernible warm front, but within the area of marked convergence ahead of the depression there was some warm air advection aloft, of a quasi-frontal type, shown by the veer of wind with height at Larkhill at 2100 on 25th, given below:—

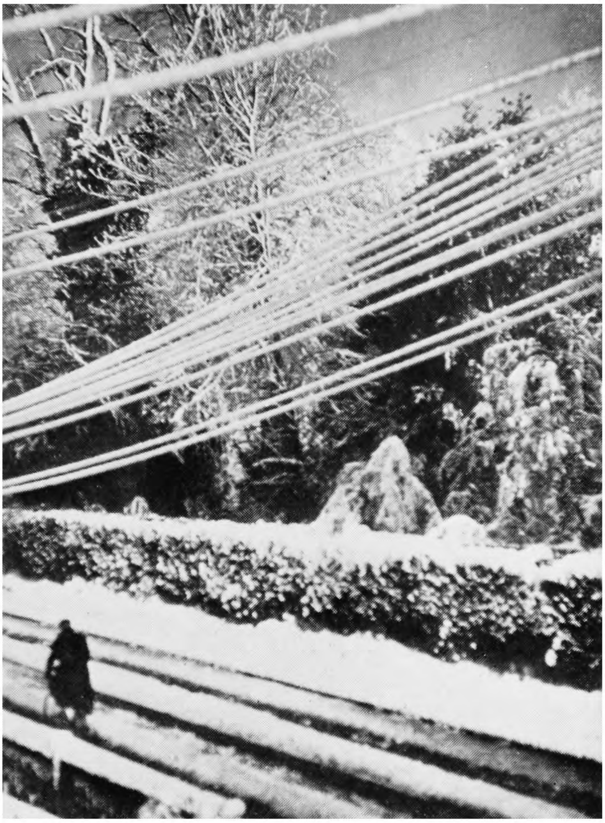
TABLE II—UPPER WINDS AT LARKHILL, 2100 G.M.T., APRIL 25, 1950

Pressure (mb.)	900	850	800	750	700	650	600	550	500
Wind direction (°true)	125	160	208	217	225	231	240	237	241
Wind speed (kt.)	14	13	16	18	25	28	29	32	40

The veer with height was most marked below the 850-mb. surface, and the lapse rate in that region was stable.

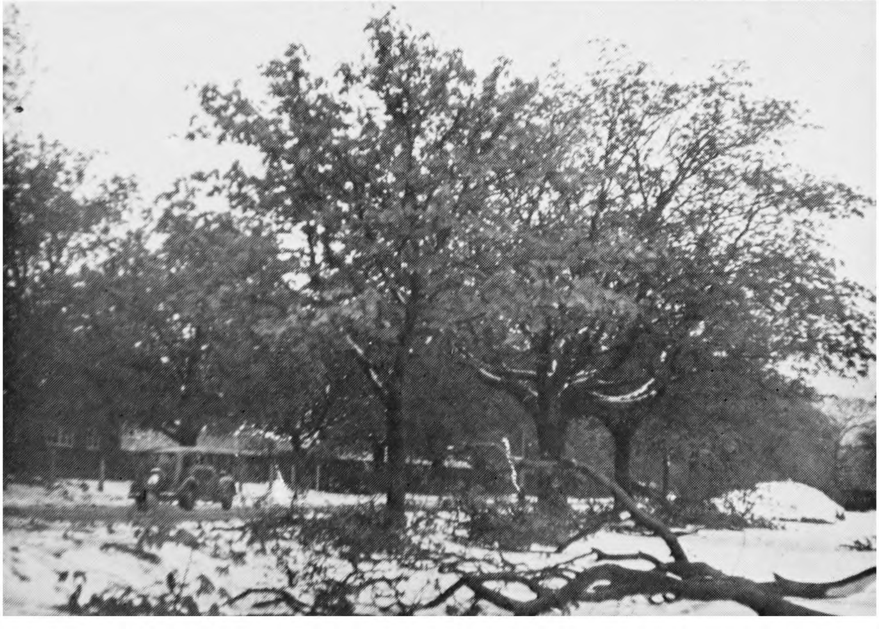
Even apart from frontal or quasi-frontal action, the circulation round the centre must tend to carry the air carrying most of the condensed moisture to the left of the track. Convergence probably has a maximum at the isallobaric minimum, but there may easily be a lag between the maximum convergence and the maximum precipitation, since it takes time to form a thick and unbroken cloud layer extending far above freezing level. When snow-flakes first form at a low temperature they are small and the time taken for them to fall through the rising air is not negligible.

Fig. 4 shows the 1000–500-mb. thickness lines (in feet) for 0300 on the 26th, and also a few sea-level isobars, which are a little different from those at midnight, and the sea-level fronts at 0300. The thickness lines are also isotherms of the mean temperature of the column of air in the layer. The winds plotted are the vector differences of wind between 950 and 500 mb. which correspond roughly to the " thermal " winds. The outbreak of arctic air formed a cold tongue from north of Jan Mayen across the eastern districts of Great Britain to France. This still existed on the morning of the 25th, the day before the snowstorm, but within the tongue there was a closed cold pool round Leuchars, where the thickness was 16,710 ft. Warm air was then advancing towards Scotland from the north-east and the cold pool moved slowly south-west although it was decreasing slightly in intensity and the movement of its associated upper depression probably induced the secondary over Ireland which gave the snowstorm. The thickness at Aldergrove dropped by 60 ft. between 0300 and 0900, and the sea-level pressure by 3 mb. During the night the cold pool moved quickly south behind the deepening secondary, and it undoubtedly played a vital part in the deepening process and in the change of the direction of movement. At 1500 on the 25th the thermal wind to 500 mb. at Larkhill was NW. 56 kt. and 12 hours later it was SSE. 12 kt. On the 26th the cold pool turned eastward behind the sea-level depression and degenerated to a minor cold tongue subsidiary to the main cold pool over the North Sea. This was formed from the more southerly part of the original cold tongue, which moved eastward on the 25th.



Reproduced by courtesy of R. M. Poulter

TELEGRAPH WIRES SAGGING UNDER THE WEIGHT OF SNOW AT SOUTH FARNBOROUGH, 0700 G.M.T., APRIL 26, 1950



Reproduced by courtesy of R. M. Poulter

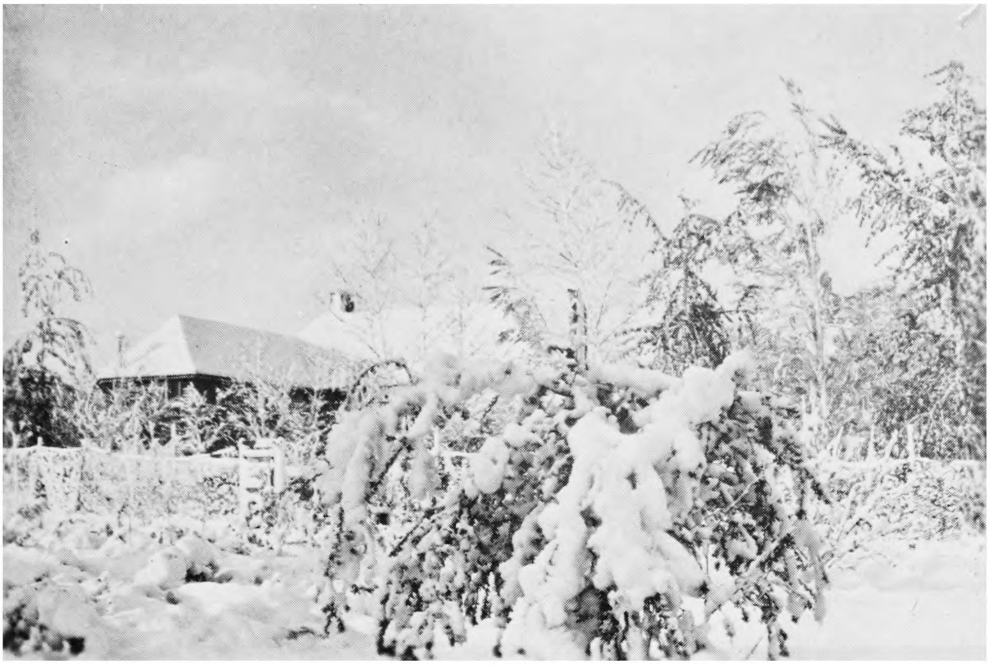
BRANCH SEVERED FROM A TREE AT ALDERSHOT, 1130 G.M.T., APRIL 26, 1950 (see p. 225)

Reproduced by courtesy of Brigadier R. E. Fryer

BRUSHING SNOW OFF A FRENCH BRISTOL FREIGHTER AT BLACKBUSHE CIVIL AIRPORT, AT ABOUT 0900 G.M.T., APRIL 26, 1950

Reproduced by courtesy of Brigadier R. E. Fryer

TUDOR HOUSE, YATELEY, CAMBERLEY, SURREY, AROUND 0700 G.M.T., APRIL 26, 1950
(see p. 225)

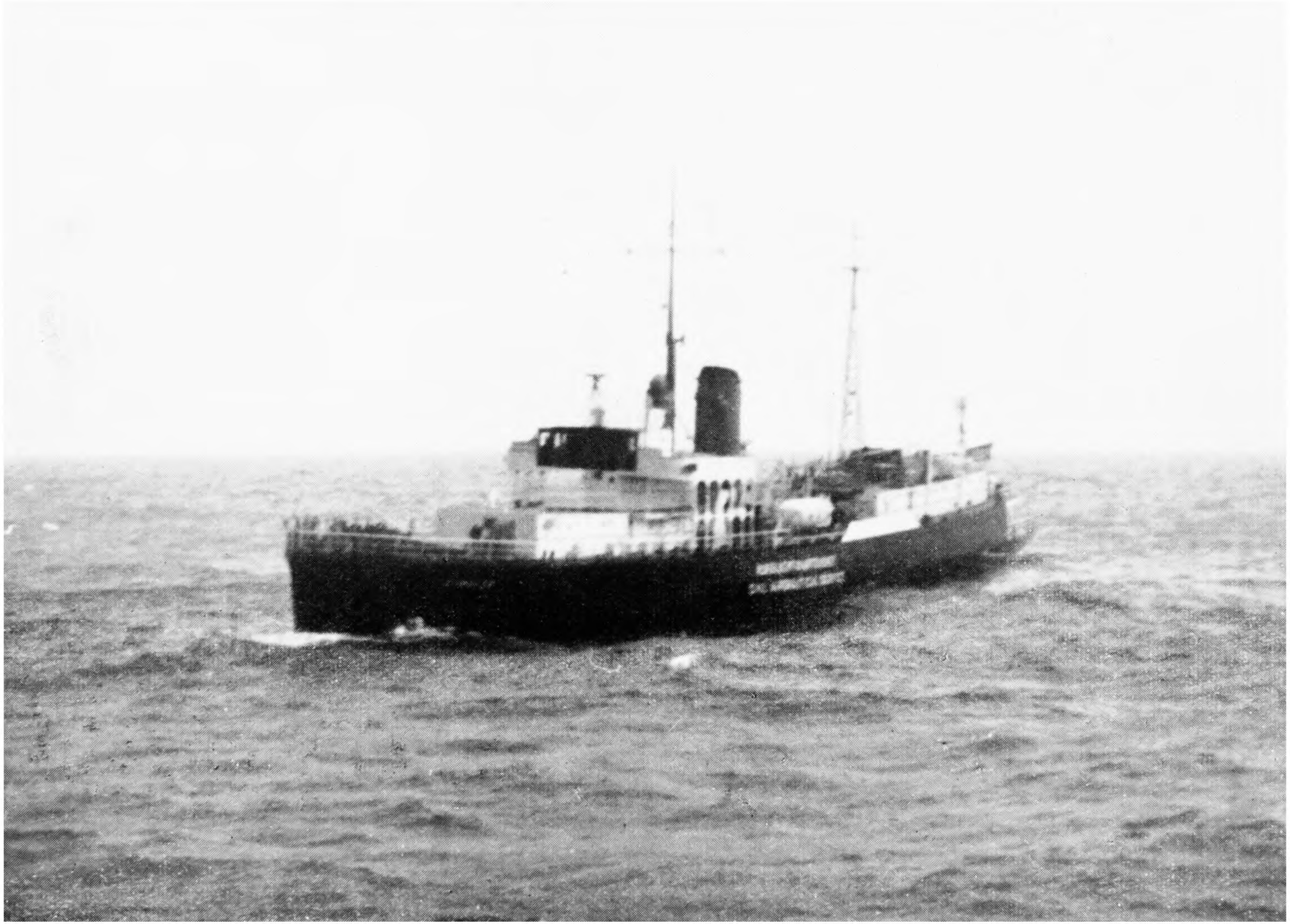


Reproduced by courtesy of Brigadier R. E. Fryer

SNOW ON THE NORTH SIDE OF A SMALL TREE, AT TUDOR HOUSE, YATELEY, AROUND 0700 G.M.T., APRIL 26, 1950
(see p. 225)

Crown copyright

METEOROLOGICAL OFFICERS OF THE NETHERLANDS' OCEAN WEATHER SHIP *Cumulus* AT STATION JIG, APRIL 1950



Reproduced by courtesy of Capt. A. W. Ford

NETHERLANDS' OCEAN WEATHER SHIP *Cumulus* AT STATION JIG, APRIL 1950
(see *Meteorological Magazine*, July 1950, p. 206)

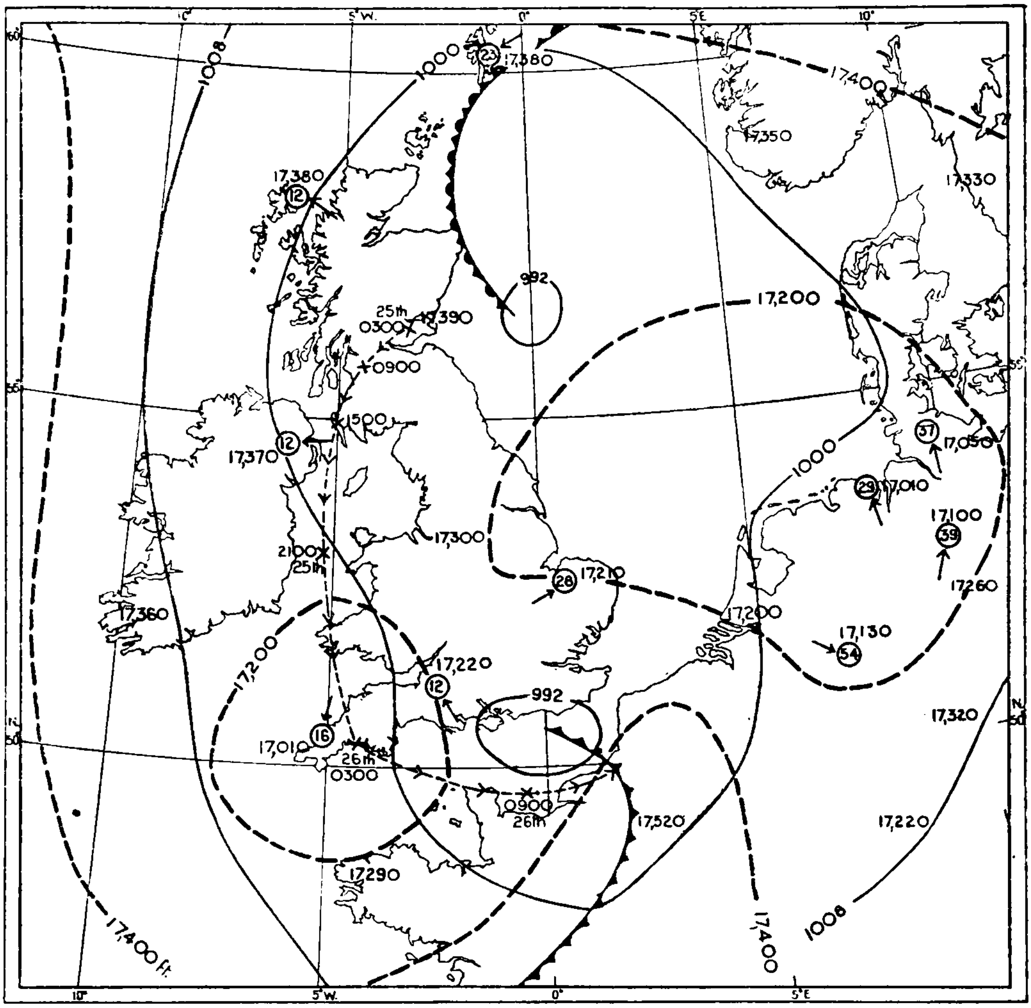

10°
5°W.
0°
5°E.
10°
60
55
50
1008
1000
17,380
23
17,380
17,400
17,350
17,330
12
17,380
992
25th
0300
17,390
0900
17,200
1500
12
17,370
1000
37
17,050
29
17,010
17,100
39
17,300
2100
25th
28
17,210
17,260
17,360
17,200
17,130
54
17,220
12
992
17,320
17,200
16
17,010
26th
0300
0900
26th
17,520
17,220
17,290
17,400
1008
17,400 ft.

FIG. 4—THICKNESS LINES OF THE LAYER 1000–500 MB., AND SEA-LEVEL ISOBARS, 0300 G.M.T., APRIL 26, 1950

Directions of " thermal " winds of the layer 950–500 mb. are indicated by arrows; speeds are given in the circles in knots

The track of the cold pool is indicated by the thin broken line

It is interesting to note how exceptionally cold was the Arctic air stream which flowed over the British Isles on April 24. Table III gives the temperature recorded on that day at various pressures compared with the average temperatures at corresponding pressures for April for the period 1942–49.

TABLE III—COMPARISON OF UPPER AIR TEMPERATURES ON APRIL 24, 1950 WITH AVERAGE TEMPERATURES FOR APRIL

	April 24, 1950	Average April 1942–49	Difference
mb.	°F	°F.	°F.
500	−23	− 5·3	17·7
600	−17	10·9	27·9
700	− 2	23·7	25·7
800	12	32·9	20·9
900	24	41·1	17·1

Dr. Belasco, in a paper on the characteristics of air masses over the British Isles to be published shortly as a *Geophysical Memoir*, gives the following data for April in direct polar air in south-east England, for the period 1931–45.

TABLE IV—UPPER AIR TEMPERATURES FOR APRIL IN DIRECT POLAR AIR OVER SOUTH-EAST ENGLAND, 1931–45

	Average	Lowest recorded
mb.	°F.	°F.
700	2	−2
800	15	12
900	28	24

The temperature in the upper air in the period preceding the snowstorm of April 26, 1950, therefore exactly equalled the lowest registered in direct polar air in April during the period 1931–45.

The modern emphasis on thickness lines in relation to development has decreased the apparent distinction between polar-air and polar-front depressions, but nevertheless there are real differences of behaviour and structure in the most typical cases. (It was always recognised that there are intermediate cases and that, as with most atmospheric phenomena, there are no sharply defined categories.) The polar-air depression deepens quickly, aided by the high lapse rate, but the period of development is short and the central pressure does not become really low unless a frontal depression is absorbed. The distortion of the thermal field is also rapid and this affects the movement of the depression. This rapid distortion is partly due to the initial thermal gradient being smaller on the average than in frontal depressions, and partly to the fact that the warm tongue with its crest over or just ahead of the rain area is maintained or even slightly intensified during the development of a polar low, whereas in the case of a typical polar-front system the thickness both over and just ahead of the sea-level centres generally decrease during the occlusion process. This is due to the fact that the air in the warm sector is usually slightly stable even when saturated, so that temperature at a fixed pressure is reduced when the air ascends. So long as this cooling is slight, it cannot markedly retard development. The importance of latent heat is enormous, whatever the precise lapse-rate, but it has to be considered in relation to the horizontal temperature gradient. The conversion of potential into kinetic energy requires that the ascending air should be on the whole warmer than the descending air. The charts show up the relative warmth of the precipitation area in the example we are discussing. After the snow the sky cleared quickly and in some areas there were a few hours with almost no cloud and intensely blue sky, indicating that some of the cold air was subsiding.

When the secondary first formed, the general conditions were showery, but there was some continuous snow close to the incipient centre. Aldergrove had 10 mm. equivalent rainfall in the 24 hours ending at 2100 on the 25th, but the precipitation was greater when the depression had become deeper and had crossed a warm sea surface. We have seen that the 2100 Larkhill wind observation showed a warm-front type of structure with advection from the west Channel area, where the surface temperature and dew point were relatively high. The warm tongue was formed mainly by advection but convection from the sea surface was operating also. The relationship between cumulus convection and large-scale ascent is not yet really understood. Thunderstorms sometimes amalgamate into quite large rain areas, often with further thunder for a time (with lightning nearly all in the clouds), and there is normally an active depression or trough moving north or north-east in summer or autumn. Energy released in the form of irregular vertical movement is dissipated by friction, but the warming of the upper layers by the release of latent heat must have some significance for general development, though its scale is small in our area.

VARIATIONS OF MEAN AIR TEMPERATURE AND HOURS OF SUNSHINE ON THE WEATHER SLOPE OF A HILL

By L. P. SMITH, B.A.

Three climatological stations are situated within 7½ miles of Aberystwyth, *viz.*:—

	Height above M.S.L.
	ft.
Aberystwyth, Health Resort Station	12
Aberystwyth, Plant Breeding Station, Crop Weather Station	452
Llety-evan-Hen, Crop Weather Station	950

Comparable daily records are available for over 20 years. In general terms, these stations can be regarded as lying on the slope of a hill-side facing south-west, (*i.e.* a weather slope as distinct from a lee slope).

The daily mean air temperatures, computed from the arithmetical mean of the maximum and minimum, have been examined on a monthly basis for the years 1929–48, together with the mean monthly total sunshine hours. These 20-yr. monthly and annual means show the following comparisons.

TABLE I—COMPARISON OF MEAN AIR TEMPERATURES AND SUNSHINE HOURS AT STATIONS ON THE WEATHER SLOPE OF A HILL

	Mean air temperature					Mean monthly sunshine hours				
				Difference					Ratio	
	12 ft.	452 ft.	950 ft.	12 ft. to 452 ft.	12 ft. to 950 ft.	12 ft.	452 ft.	950 ft.	452 ft. to 12 ft.	950 ft. to 12 ft.
	degrees Fahrenheit					*hours*			*per cent.*	
January	41.08	39.61	37.67	1.47	3.41	59.15	58.89	53.19	99.6	89.9
February	40.65	39.20	37.17	1.45	3.48	75.17	71.59	66.73	95.2	88.8
March	43.93	42.91	41.47	1.03	2.47	130.26	126.32	119.01	97.0	91.4
April	47.54	46.25	44.52	1.29	3.02	158.78	153.65	142.33	96.7	89.6
May	52.27	51.11	49.49	1.15	2.79	197.86	191.75	181.63	96.9	91.8
June	57.45	55.99	54.29	1.45	3.15	194.28	190.92	177.89	98.2	91.6
July	59.95	58.40	56.41	1.55	3.53	151.89	145.70	130.75	95.9	86.0
August	60.81	59.17	57.41	1.65	3.40	174.48	165.49	152.53	94.8	87.4
September	57.85	56.19	54.21	1.66	3.63	134.12	127.86	116.43	95.3	86.8
October	52.05	50.41	48.35	1.64	3.69	100.38	95.99	86.37	95.7	86.0
November	47.07	45.54	43.64	1.53	3.43	56.37	55.71	49.86	98.8	88.5
December	43.30	41.99	40.07	1.31	3.23	48.45	48.84	43.47	100.8	89.7
Year	..	..	..	1.43	3.27	..	..	..	97.12	88.96

These results are also shown in Figs. 1 and 2. The mean annual differences in temperature correspond to a fall of 1°F. per 308 ft. for the 12-ft. to 450-ft. rise, and 1°F. per 288 ft. for the 12-ft. to 950-ft. rise. The normal rule of thumb lapse of 1°F. per 300 ft. is therefore not greatly divergent from the observed results for these stations. The fall in temperature with height is least noticeable in spring, especially March and May, and most in summer and autumn.

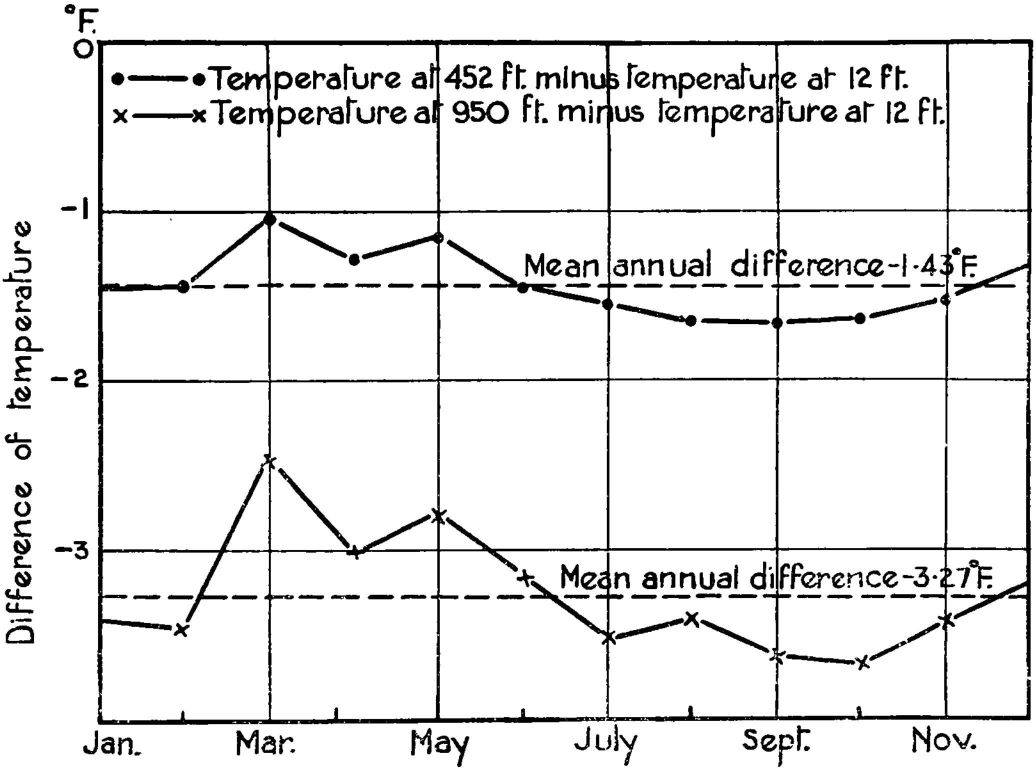


FIG. 1—DIFFERENCE OF MEAN MONTHLY AND ANNUAL TEMPERATURES AT STATIONS ON THE WEATHER SLOPE OF A HILL

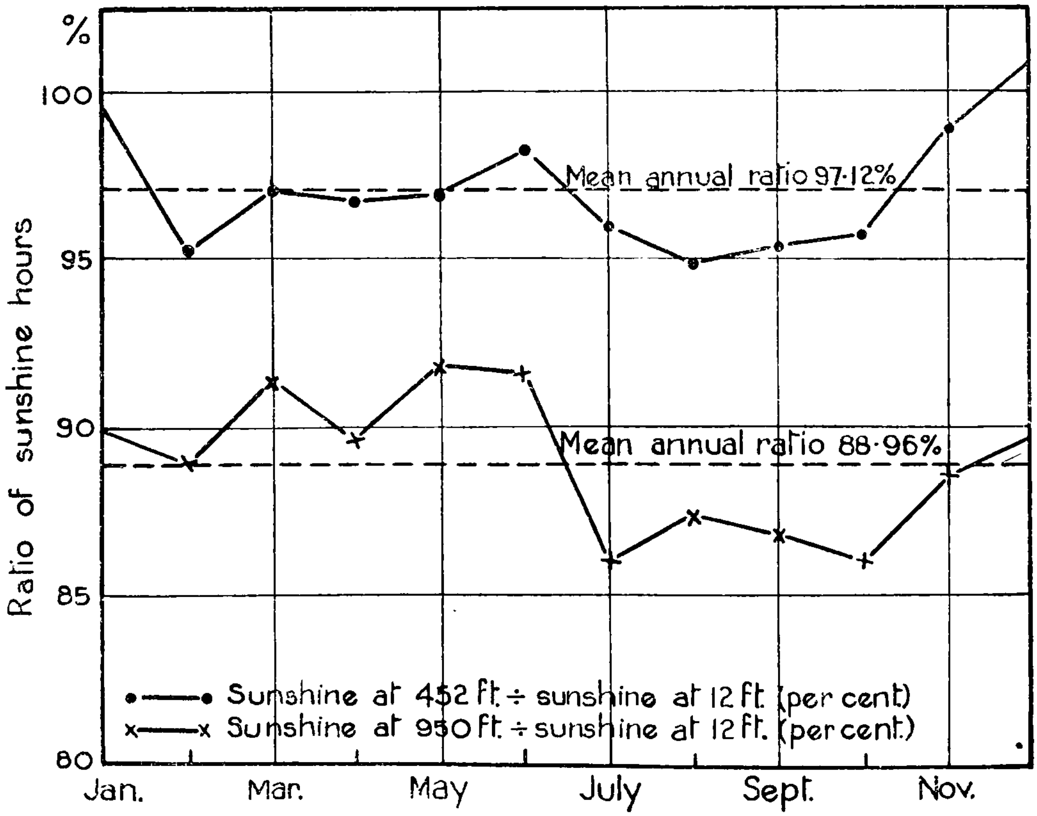


FIG. 2—RATIO OF SUNSHINE HOURS AT STATIONS ON THE WEATHER SLOPE OF A HILL

The mean annual sunshine ratio does not vary linearly with height, in fact, the above figures fit a formula:—

Decrease in percentage with height$=0{\cdot}22h^{7/4}$

where h is measured in hundreds of feet. The decrease is most apparent in late summer and early autumn, it is least at 452 ft. in winter and at 950 ft. in spring and early summer.

METEOROLOGICAL RESEARCH COMMITTEE

The tenth meeting of the Physical Sub-Committee was held on May 31, 1950. The report on the measurement of temperature and humidity gradients in the first hundred metres at Rye[1] was discussed. A paper by Dr. Robinson and Mr. Rider on the transfer of heat and water vapour above a surface of short grass[2] was also considered.

Other branches of meteorology were represented by a paper on drop-size distribution in cloud[3] and by a paper by Miss N. Carruthers which summarised the results of some upper air soundings at Nairobi[4].

[1] *Met. Res. Pap., London*, No. 546

[2] *Met. Res. Pap., London*, No. 547

[3] *Met. Res. Pap., London*, No. 559

[4] *Met. Res. Pap., London*, No. 554

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society on May 17, 1950, with Mr. L. C. W. Bonacina, Vice-President, in the Chair, papers were read by Dr. J. S. Forrest on "Variations in thunderstorm severity in Great Britain" and by Mr. S. Morris-Bower on "Recent work of the Thunderstorm Census Organization".

Dr. Forrest's paper describes the relation between the number of break-downs caused by lightning over the whole of the British Grid system of high-voltage transmission lines and the number of days on which thunder was heard at eight meteorological observing stations, Renfrew, Eskdalemuir, Tynemouth, Birmingham, Kew, Southampton, Stoneyhurst and Long Ashton, selected so as to represent the area covered by the Grid so far as possible in relation to the density of the grid lines. Dr. Forrest explained that break-downs might occur when lightning struck either the earthed line or one of the power lines and led to a flash-over across the insulators of the power lines or from power line to earth line. A lightning strike might occur to a line without causing a break-down. He considered that the Grid would intercept strokes falling within a triangle with vertex on the line and base twice its height.

He gave tables and figures of the thunderstorm days observed at all the eight stations and total break-downs in each month and year of the 14 years, 1933–47. The total numbers of break-downs in each year followed quite closely, though with a much greater range, the thunderstorm days in each year and the two had a correlation coefficient of 0·74. The two sets of monthly totals were also very similar, with correlation coefficient of 0·97, though again the break-downs had a greater range.

The diurnal variation of break-downs had a primary maximum at 1600–1700 G.M.T., a very secondary one between 0300 and 0600, and a minimum between 0700 and 0900. The meteorological data for comparison with this were available only for Kew* and they revealed a maximum of thunder somewhat earlier in the afternoon but no early morning secondary maximum.

Dr. Forrest ascribed the correspondence between the two sets of data, with a greater range for break-downs, to a power-law relationship of the form $N=kT^s$ between N the number of break-downs, T the corresponding number of thunderstorm days, k a constant, and $S(>1)$ an index which he termed the " severity index ". He showed that S was about 1·9 for the annual variation and about 1·4 for the monthly one. The difference between the two indices he ascribed to the monthly totals being dependent on the different characteristics of winter and summer thunderstorms.

He concluded by stating he considered that statistics of " thunderstorm days " were misleading as a measure of the total severity of thunderstorms and that a better measure was obtained by applying an appropriate severity index to them.

Mr. Morris-Bower said he considered statistics of thunderstorm days based on observations of " thunder heard " were convenient but weak, as whether an observer heard thunder or not depended very much on the observer's location and assiduity. He had found it was difficult to draw any charts based on days of " thunder heard " as the number of days over a period could vary by 50 per cent. between stations three or four miles apart. He much preferred the more definite observations of thunder overhead which were recorded by observers for the Thunderstorm Survey. He described the methods of collecting and plotting the data used by the Survey.

The relation between the number of observations of overhead thunder obtained by the Survey and Dr. Forrest's Grid break-downs was, he explained with figures, very good, but the afternoon maximum of break-downs was two hours later than the overhead thunder maximum and the monthly averages did not show the sharp peak in July that the break-downs did. Better correspondence was shown by the annual variation of the areas covered by " overhead " storms. He showed charts of areas of " overhead " thunder for the year 1932 and for the annual average and also charts of isochrones of overhead thunder for a particular day.

Mr. Shipley said a more reliable statistical index of the severity of lightning than " thunderstorm days " was much needed as there was a very large variation in the frequency of lightning flashes in individual storms; it was possible to have 120 flashes a minute. He thought Dr. Forrest's criterion was the best yet produced but also that the minor distribution lines were more liable to damage. In view of the greater winter frequency of storms in Cornwall he thought Bristol was not representative for the south-west.

Mr. Oakeshott thought it might be possible to use the data provided by an atmospheric recorder for measuring severity if it were possible to distinguish between flashes in the clouds and flashes to earth. Mr. Ryle said the break-down rates in South Africa were ten times higher than in Britain and gave a severity index 2·5 times Forrest's value for Britain. The results all suggested that the more storms there were the more severe they were. Dr. Golde said the Electrical Research Association was investigating the relation between the line break-downs and the observations of the 250 stations recorded in the *Monthly Weather Report.*

Mr. Ludlam said the water content of clouds and so the severity of storms was determined mainly by temperature and it should be possible to correlate

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*BISHOP, B. V.; The frequency of thunderstorms at Kew Observatory. *Met. Mag., London,* 76, 1947, p. 108.

break-downs with temperature. The sharp afternoon maximum in break-downs showed that such thunderstorms build up quickly and he thought the early morning maximum was due to storms produced originally over France. Dr. Scrase said that, though the Kew observations of thunder heard did not show an early morning maximum, the Kew point-discharge records did.

Dr. Robinson asked what it was that the Census maps showed isochrones of, and Mr. Jacobs referred to the United States Thunderstorm Project results which showed the movement of thunder cells of diameter about three miles which developed, died away, and set off similar cells.

Dr. Forrest, in his reply, said he had estimated from the frequency of flashes that about one flash in twenty-five to a grid line caused a break-down and explained to Mr. Gold that the average length of line concerned is about twenty miles. The early morning maximum was not confined to incidents in coastal areas.

Mr. Morris-Bower said the movement shown by the isochrones was of a thundery tendency, and that the census had found that an early morning maximum of overhead storms was most pronounced over the western part of the country.

LETTERS TO THE EDITOR

Frequency of wind and radiation frosts

Mr. Hogg's article on the relative frequency of wind and radiation frosts* presents a very pessimistic picture to the fruit-grower. If one frost in four is a wind frost of the form adequately defined by East Malling Research Station then all attempts at preventing frost damage are pointless.

However, the picture is not quite so black as this because a meteorologist's general view does not conform with the view a grower must take to decide how to protect his fruit. Mr. Hogg bases his correction factor for the error involved in measuring the wind speed at 0900 G.M.T., long after the frost has finished, on measurements of the mean hourly variation of wind speed on mornings when there is a light breeze. However, on nights when this wind has persisted from 0400 at this speed a frost is extremely unlikely. On the occasion when frost has occurred the wind speed by night has probably been very much lower (particularly nearer the ground and after all how few valuable trees now bear fruit 30 ft. from the ground). The general mean therefore bears little relation to the figures that a fruit-grower requires. He wants to know, on the average, whether or not a wind was blowing at 0400 during all nights when a frost occurred in May.

Our limited experience of sitting up with a frost all night has shown us how frequently an absolute calm at dawn can become a force-2 wind at sunrise, and also how frequently a wind blowing less than 2 m.p.h. 6 ft. from the ground can prevent that disastrous pooling of cold air, which the growers dread, even on the clearest of nights.

Wind frosts do occur and are dangerous, but are less frequent than Mr. Hogg's analysis would appear to show.

National Institute of Agricultural Engineering,
Wrest Park, Silsoe, Bedfordshire,
April 18, 1950 R. J. COURSHEE

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*HOGG, W. H.; Frequency of radiation and wind frosts during spring in Kent. *Met. Mag., London,* **79**, 1950, p. 42.

[It may help if I first explain how the data were extracted. The night minimum temperature and the wind force at the morning observation were extracted for each day. If the minimum temperature was 32°F. or less, the frost was assumed to be a radiation frost, provided the wind did not exceed force 2; frosts with winds above force 2 were provisionally classed as " wind frosts ". The next step was to decide what proportion of these wind frosts should in fact be classed as radiation frosts because of the diurnal increase in wind speed between the time of minimum temperature and the morning observation. The method was explained in the article, but I would emphasise that Table I refers only to days when the mean hourly wind speed fell (at about 30 ft.) below 7·5 m.p.h. around dawn; on most of these days the wind speed was well below this for the whole of the time.

I have re-computed Table I for the nights on which frost occurred, with the following result:—

	0500	0600	0700	0800	0900
			miles per hour		
March	3·5	3·5	3·9	4·3	5·8
April	2·4	2·2	2·6	3·3	4·9

Only 2 frosts occurred in May.

These mean wind speeds give the following correction factors: March 0700, 4/50; March 0900 23/50; April 0700, 2/50; April 0900, 25/50. There would therefore be no appreciable difference in the frequency of wind frost in March using these criteria, but the frequency of wind frost in April would be increased.

I agree that there would probably be little damage at 30 ft. on most trees, and for that reason I suggested that the use of 7·5 m.p.h., instead of 5 m.p.h., as a limiting value was probably no disadvantage.

On general grounds Mr. Courshee's letter raises the problem of the application of meteorology to agricultural problems. I think it is now generally agreed that special observations are needed for these problems, and I understand that more of them are being made. It will, however, be many years before there are sufficient of them to use as " normals " (if this term can be used in connexion with agricultural meteorology, where almost every site is unique). Meanwhile, how can the meteorologist best help the agriculturist? One way is to use standard observations, making estimates where the original data are not in a form suitable for direct application to agriculture. Another possiblity, which I think has not yet been tried, is to estimate the frequency of the synoptic situation which is likely to produce the agricultural hazard.—W. H. HOGG]

Temperature rise on clear mornings

Mr. Jefferson, in his interesting article in the *Meteorological Magazine* for February 1950[*], says that the curves on p. 38 take the general form of a sine curve. But the top curve, which runs off to infinity, is more like part of a secant curve.

If the influx of energy throughout the year, as represented by Gold's numbers, varies as an approximate sine curve, say

$$y = a + b\sin x$$

then, neglecting the annual variation in the length of the hours of sunshine, one would expect the " hours from sunrise " curve to take the form of the reciprocal function, *i.e.*

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[*] JEFFERSON, G. J.; Temperature rise on clear mornings. *Met. Mag., London,* **79**, 1950, p. 33.

$$y = \frac{1}{a + b\sin x}$$

This equation gives curves similar to the top curve on p. 38 when $a \leqslant b$, and it gives curves similar to the others, *i.e.* with a flat minimum and pointed maximum, when $a > b$

Calshot, Southampton, April 20, 1950 G. A. INGLIS

[Mr. Inglis in his comments has provided a general formula which appears to fit the curves given in Fig. 3. My remark that they followed the general form of a sine curve is perhaps somewhat open to misinterpretation. My purpose in drawing the curves of best fit to the points plotted was to ascertain the corrected monthly mean values of times from sunrise given in Table II, and at the time I made no attempt to provide a formula for the curves but intended to note in passing that most of them bore a general resemblance to a sine curve. However, the formula given by Mr. Inglis applied to the curve for 0·5 cm.^{2} of energy in Fig. 3 as an example becomes, assuming maximum in December,

$$y = \frac{1}{0{\cdot}37 + 0{\cdot}15\sin\tfrac{\pi}{6}(m-3)}$$

where y is the monthly average time from sunrise for sunshine to provide energy equivalent to 0·5 cm.^{2} in the month m (numbered January$=1$, February$=2$, March$=3$, etc.) and constants a and b are equal to 0·37 and 0·15 respectively. Values for a and b can be evaluated for each of the curves given, and similarly this could be done for other stations with different soil characteristics giving monthly values different from those of Table II.

Pursuing this idea it should be possible to obtain the monthly values for other stations by ascertaining suitable values for constants a and b thereby short-circuiting the somewhat long procedure for obtaining them by the original method as outlined in the paper. This would make the results of more general application.—G. J. JEFFERSON]

NOTES AND NEWS

Tropical rainfall from cloud which did not extend to the freezing level

In the issue of the *Meteorological Magazine* for October 1948, Mr. A. C. Best asked for authentic cases of rain in the tropics from cloud which did not extend up to the freezing level. The following notes have been contributed by Meteorological Officers in the West Indies.

Mr. Wallace of the Meteorological Office, Nassau, Bahamas, supplies the following comments: "There is not the slightest doubt that precipitation in quite appreciable amounts occurs fairly generally in the Bahamas area from cloud, usually a combination of cumulus and stratocumulus, with very little vertical development, and that large amounts of summer rainfall result from cumulus which, although well developed, does not reach the freezing level at approximately 15,000 ft. Instances of the latter are rather difficult to substantiate as they are for the most part of a transitory nature but the winter type of precipitation occurs under a marked anticyclonic inversion which persists almost throughout the dry season, broken only by the passage southwards of occasional cold fronts. The base of the inversion is remarkably constant between 4,500–6,500 ft. and above it humidities are extremely low, frequently less than 10 per cent. Accurate reports have been recently obtained of this cloud structure on occasions of precipitation by aircraft operating in this area. The most striking example so far occurred on December 15, 1949, when showers were reported from a mixed layer of cumulus and stratocumulus base 1,500 ft. top 5,300 ft. 3.3 mm. of rain were recorded at Oakes Field, Nassau, in two showers around the dawn period (0930–1020 G.M.T.) and 1219–1255 respectively. The freezing level at the time was 15,000 ft. At 1500 the Miami radio-sonde gave the base of the inversion at 840 mb., temperature 46°F. and dew point 43°F. The top of the inversion was at 790 mb. with a temperature of 57°F. and a dew point of 18°F. This sounding showed no appreciable change from the previous one twelve hours earlier. The sky above the inversion was completely clear of cloud. Another instance was reported by a B.O.A.C. pilot at 1500 on January 11, 1950, five miles north-east of New Providence en route to Bermuda. Heavy precipitation was observed on this occasion down to the surface from cloud whose tops did not exceed 6,800 ft. The freezing level was 13,500 ft. The Miami radio-sonde indicated an inversion between 810 mb. and 750 mb., temperatures 46°F. and 50°F. respectively."

In addition an analysis was made at Piarco, Trinidad, of cloud tops reported from pilots flying round the triangle, Trinidad, Barbados and Grenada. On 75 per cent. of days in 1946 cloud was reported not to reach the freezing level. Yet at Seawell, Barbados, in 1946, there were 184 days with rain; at Piarco, Trinidad, there were 236 days with rain; and at Pearls Airfield, Grenada, there were 210 days with rain: evidence that a fair proportion of the rain fell on days when the cumulus did not extend to the freezing level.

A particular case may be mentioned: On March 22, 1948, an airline pilot remarked that quite considerable rain was falling over Barbados from cloud of which the tops did not extend above 9,000 ft. (although the freezing level was 15,000–16,000 ft.). Over leeward parts of the island the rainfall for the day averaged about 8 mm., while one gauge on the eastern slopes of the island recorded the maximum reading for the day, 17 mm.

S. E. VIRGO

REVIEW

Climatology. By W. G. Kendrew. 8vo. 8½ in. × 5½ in. pp. 383. *Illus.* Oxford University Press, 1949. 30*s.*

The third edition of Mr. Kendrew's " Climate ", which appears now under the new title of " Climatology ", is very welcome and Mr. Kendrew is to be congratulated on the skilful and thorough way in which he has brought the book up-to-date.

The general arrangement is similar to that of the second edition except that there are six parts in place of ten. Of these the first three deal with the meteorological elements: insolation and temperature; atmospheric pressure and winds; vapour and its condensation (including rain, cloud, sunshine and visibility) and the last three with the climate of different regions: mountain and plateau climate; the weather of the westerlies; some climatic types (Sudan, Mediterranean and westerlies). The main change in arrangement is the combination of the three parts dealing with water vapour into a single part, and the transfer of the descriptions of local winds into Part II. This, however, does not give an adequate idea of the changes. The whole book has been almost entirely rewritten, many of the diagrams have been redrawn and new plates and figures inserted, chapters have been added on air masses, frontal weather and the upper air, and the volume is written with much more reference to the physical causes which lie behind the different manifestations of climate. The change of title from " Climate " to " Climatology " is well justified.

Almost every part of the book has been amplified. There are new sections on the thermal properties of land surfaces—a very important factor in climatology—the heat balance of the earth, turbulence and the effect of obstacles on air currents, to mention only a few. The discussion of the " trade winds " has been carried into the upper air, with a description of the inversion; the chart of rainfall has been extended over the sea; the sections on frozen precipitation have been added to, and the effect of atmospheric pollution is discussed with a very telling photograph. The new plates include a beautiful illustration of the climatic contrast between sunny and shady slopes in the Alps(Plate 12).

The good use which the author made of his war-time opportunities in Africa is evident in many places, particularly in the interesting diagram of wind and clouds over Lake Victoria on p. 120, the influence of Table Mountain on rainfall (p. 192), the charts of the lee depression of Madagascar (p. 302) and in the photograph of cumulonimbus on the equator(Plate 6).

There is a short but useful bibliography which has also been brought up to date, though one misses reference to many of the modern meteorological atlases. The fact that the only atlas dealing with the world is dated 1899 shows that climatology still lacks adequate international organization.

The index has been entirely remade, not, in the opinion of the reviewer, an improvement. There is too much grouping of all entries under the main elements so that it becomes almost a classified table of contents. Some of the elements have twenty or thirty sub-headings and more than 100 page references. Geographical names and names of authors have been omitted entirely. For deserts one is told to " see Trade winds ", but is left guessing as to which of the twenty odd references one should see. Such words as " Geostrophic ", " Stratosphere ", " Tropopause " are not there at all. Often one needs an index to trace some minor fact rather than to find the major sections but for that this index is of little help.

In a volume of this size, of which every page is full of facts and figures, some errors are inevitable, especially when it is the work of a single author. One of the more serious is in the visibility scale on p. 267 where the descriptions of some of the code numbers are wrong; incidentally a cross-reference on p. 319 to the page where the code is given would be useful. One could wish also that the author had been more consistent about units, though admittedly there may be something to be said for training students to be, so to speak, multilingual. Isobars in inches (Figs. 42–3) take one back almost to Edwardian days. In the companion diagrams of Figs. 91 and 101 sunshine is given in one in hours/month and in the other in hours/day. There is some inconsistency, too, in some of the figures quoted in the tables such as those for Kabete with a mean monthly minimum of 40° and an extreme minimum of 41°. Discrepancies of this sort emphasise the minor trials of the climatologist and are almost inevitable where the data are based on different periods all of short length. In the bibliography Clarke has lost the " e " which he rightly had in the text, Mr. Newnham has been credited with his wife's work on hurricanes, and Abercromby has gained an " ie " after revision by Goldie.

To ask for additions to a book already so full of information may seem ungrateful, but it perhaps may be permitted regarding a book which is likely to run to many more editions and to be a standard in its class for years to come. First, one would like an index of the stations referred to, with their geographical co-ordinates and height (not all meteorological stations are given even in a modern atlas): secondly, some indication of the periods on which the data are based (it is difficult to interpret the significance of some of the extremes without it): and thirdly, a brief glossary of terms which if it did nothing else might help climatologists to come to some agreement about the use of such words as mean, average and normal.

However, these are minor points and the book should certainly be on the shelves of all meteorologists; it brings the study of climate to life as few other books do.

E. E. AUSTIN

METEOROLOGICAL OFFICE NEWS

Obituary.—It is with deep regret that we record the death of Mr. J. C. Lister and the fellow members of the crew of the Meteorological Halifax aircraft which crashed on Achill Island off the west coast of Ireland on its return from a " Bismuth " Meteorological Reconnaissance Flight on June 16, 1950.

Mr. Lister was a Meteorological Assistant prior to his call-up for national service. He was successful in the 1949 A.E.O. competition and on his release from the Forces would have taken up appointment in an established post as Assistant Experimental Officer. He was, therefore, at the beginning of a promising career as a meteorologist. On joining the R.A.F., Mr. Lister had volunteered for observational duties in meteorological reconnaissance aircraft. He had completed his training and had been promoted to Air Meteorological Observer IV immediately prior to the accident.

His present and former colleagues in the Meteorological Office extend their deepest sympathy to Mr. Lister's parents in their loss.

Establishment of assistants—competitions.—A series of short refresher courses for assistants will begin in September 1950 at the Meteorological Office Training School. Temporary assistants who have failed in the 1950 competition for establishment should note that they will be given an opportunity to attend one of these courses. They would be well advised, however, not to wait until attending a course before " brushing up " their physics and mathematics.

The Meteorological Office, Edinburgh, has been at No. 6, Drumsheugh Gardens since 1925. Owing to expiry of lease it has become necessary to find a new home and the Office moved to No. 26 Palmerston Place on June 10, 1950.

Upper air statistics and research.—Some six years ago a section was formed at Harrow to collect and summarise upper air data for the stations at home and abroad under the control of the Office. It is of interest to look back and see how the work of this section has developed and what progress has been made.

Early in 1944 it was realised that, with the development of jet aircraft, there would be an urgent demand for information on winds at high levels all over the world. This led Dr. Brooks and Mr. Durst to devise methods by which the mapping of the winds up to 200 mb. (about 38,000 ft.) could be done by interpolation. These methods involved much calculation and occupied a great part of the time of the staff for some three years. The results will shortly be published as *Geophysical Memoir No.* 85. A complement to these maps of high-level winds in the form of maps of upper air temperatures is now in course of preparation as the second major undertaking of the section. In January, 1948, the Hollerith method of punched cards was adopted for recording and analysing the data.

Married quarters.—Reference was made in the April number to married quarters at Changi. It is encouraging to report that all U.K.-based staff serving there are now accommodated in official quarters, four being in married quarters and two single men in the R.A.F. Mess.

Falkland Islands.—During the war the Naval Meteorological Service established a meteorological office at Port Stanley in the Falkland Islands. In 1946 control of this office was handed over to the Meteorological Office and in the following year the work was extended by the addition of a radio-sonde station. Since 1944 a network of meteorological stations has been in operation in the Antarctic Dependencies under the auspices of the Falkland Islands Dependencies Survey. Following a recent reorganisation, the office at Port Stanley and the stations are being co-ordinated into a small meteorological service with headquarters at Port Stanley. This service forms an integral part of the Falkland Islands Dependencies Survey. The Meteorological Office continues to administer the radio-sonde/radar-wind station at Port Stanley.

Most of the observers at the Antarctic bases are assistants (scientific) on loan from the Meteorological Office; each base is manned by a couple of observers. News from them is sparse for the good reason that their only means of communicating with the outside world is by wireless, and the cost of sending private messages is considerable. The Falkland Islands Dependencies Survey have recently again asked the Meteorological Office to help in recruiting; a note giving particulars of the posts has been distributed.

Sports activities.—From time to time in these notes we record the progress that the Office has made in its efforts to retain the Bishop Shield. The following remarks about the Shield, and the competition for it, may be of interest to members of the staff.

The Bishop Memorial Shield was presented by the staff of the Directorate of Aeronautical Inspection in memory of the late Major P. Bishop, C.B.E., A.S., who devoted much of his spare time to the cause of sport in the Air Ministry up to the time of his tragic death in the disaster to the Airship R.101. For the purposes of the Shield Competition, the Air Ministry and the Ministry of Civil Aviation are split up into a number of divisions, which compete against one another in athletics and sports, the Shield being awarded each year to the division with the best record. Points may be gained for football, cricket, netball, lawn tennis, table tennis, swimming, chess and athletics. Each competition is brought to a close with the Annual Sports, which will be held this year on Wednesday, August 30.

The Meteorological Office won the Bishop Shield twice before the war and was again successful last year. Great efforts are being made to win it again this year and so far the number of points earned is 70. Any staff who wish to help the Office in the various events are invited to get in touch with the Sports Secretary, Mr. H. S. Scotney, Meteorological Office, Air Ministry.

Staff who have not had an opportunity of attending a sports meeting will also be interested in two other trophies competed for annually. The Simpson (Victor Ludorum) Cup was presented by the staff of the Meteorological Office in recognition of their regard for Sir George C. Simpson, K.C.B., F.R.S., and his interest in Air Ministry sports. Sir George Simpson retired from the post of Director of the Meteorological Office in 1938. The Cup is presented at the Annual Sports to the champion athlete in certain individual events during the year.

The W. S. Jones Memorial Cup was presented in memory of the late Mr. W. S. Jones who, in addition to being Chairman of the Staff side of the Air Ministry Whitley Council in 1927-28, was an enthusiastic helper in the efforts to finance the Air Ministry sports ground at Waddon. The Cup is awarded to the division scoring the highest number of points at the Annual Sports, in individual championship events and inter-divisional relays.

BOOKS RECEIVED

Low stratus clouds over Bangalore, by P. A. George. *Sci. Notes met. Dep. India*, **10**, No. 123. Size: 10 in. × 6½ in., pp. 14. *Illus.* India Meteorological Department, Poona, 1948. *Rs.* 2/8/- or 4s. 0d.

WEATHER OF JUNE 1950

Mean pressure was above 1020 mb. from the Azores and Madeira westwards to Bermuda. It was below 1010 mb. in an area extending from northern Scandinavia across the Faeroes, Iceland and southern Greenland to central Canada, and below 1010 mb. also in the south-western part of the United States; between Labrador and Hudson Bay pressure averaged about 1005 mb.

Deviations from the normal were generally small over Europe, the North Atlantic and North America. There was an excess of about 2—4 mb. over the northern part of the Mediterranean and Central Europe, and a similar excess over the Great Lakes and adjacent parts of Canada. A deficiency over the north-eastern part of the North Atlantic, Greenland, the Arctic Ocean and the northern and north-western parts of Europe, amounted to as much as 5 mb. between the Shetlands and Iceland, and to 7 mb. in the Faeroes.

The weather in the British Isles was warm generally, sunny in England and Wales and South Scotland, and mainly dry in England and Wales but very wet in north-west Scotland. During the first week a ridge of high pressure extended across the British Isles from anticyclones over south Scandinavia and Germany and maintained very warm, sunny and mainly dry weather. Local thundery rain or thunderstorms occurred, however, in southern England on the 2nd, when 2.60 in. was registered at West Molesey (Surrey) and 2.33 in. at Hampton (Middlesex), while weak, slow moving troughs off our western seaboard were associated with some rain in Ireland and Scotland from the 2nd to 4th. The period 3rd—7th was very warm; day temperatures exceeded 80°F. at some places and reached 89°F. at Squire's Gate and London Airport on the 6th. On the 7th and 8th a cold front moved south-east across the country causing rain locally in west and north Scotland and in Ireland. Temperature fell considerably in west Scotland and Ireland on the 7th and in other districts on the 8th with the passage of the cold front. On the 8th and 9th a wedge associated with the Azores anticyclone moved in over the country, while a trough to the north-west of Scotland moved east; some rain occurred in the north-west. Subsequently an anticyclone over our southern districts moved slowly north-east, while a shallow depression west of Portugal moved north-west and an associated trough moved north. Temperature rose and mainly fair weather prevailed on the 10th and 11th. The trough continued to move slowly north on the 12th, and on the 13th a weak cold front moved south across Scotland. Thunderstorms occurred locally in the southern half of the country on the 13th. Sunshine totals were very high for the first thirteen days, particularly in England and Wales. On the 14th a trough moved south-east over England and moderately heavy rain occurred over a considerable area.

From the 15th to 23rd the pressure distribution was very complex but mainly cyclonic. On the 15th a shallow depression near Denmark moved north, while another north of Scotland moved south-east. On the 16th a secondary depression formed off north-west Scotland and moved south-east; this was followed by another secondary off west Scotland which moved east and turned north. Again from the 19th to 21st yet another disturbance near Iceland moved east and then south-east, being centred in the southern North Sea on the morning of the 22nd. On the 23rd a secondary depression moved quickly east across southern England. During this period cooler weather prevailed, with rain or showers at times, but there was little rainfall in the south-east until the 19th. From the 20th to 22nd thundery rains or thunderstorms occurred rather widely, and at times rainfall was moderately heavy locally. Scattered thundery rain occurred in south-east England on the 23rd.

On the 24th an anticyclone developed over France and a warm south-west to west type of weather was established over the British Isles which lasted until the end of the month. Atlantic depressions moved north-east off our north-west seaboard giving rain in the west and north but mainly fair weather prevailed in the south-east. Among heavy falls of rain in the last week may be mentioned 3.16 in. at Hafod Fawr (Merioneth) and 2.20 in. at Blaenau Festiniog (Merioneth) on the 26th and 2.53 in. at Achnashellach (Ross and Cromarty) on the 28th.

The general character of the weather is shown by the following provisional figures :—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ..	92	36	+4·0	77	−2	122
Scotland	88	31	+2·8	123	0	94
Northern Ireland ..	84	39	+3·1	96	−1	106

RAINFALL OF JUNE 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square	1·35	67	*Glam.*	Cardiff, Penylan	1·29	51
Kent	Folkestone, Cherry Gdn.	·94	48	*Pemb.*	St. Ann's Head	2·18	104
,,	Edenbridge, Falconhurst	1·16	53	*Card.*	Aberystwyth	2·49	102
Sussex	Compton, Compton Ho.	2·04	82	*Radnor*	Tyrmynydd	1·73	53
,,	Worthing, Beach Ho.Pk.	·58	33	*Mont.*	Lake Vyrnwy	2·40	75
Hants	Ventnor, Roy. Nat. Hos.	·88	48	*Mer.*	Blaenau Festiniog	9·15	141
,,	Bournemouth	1·12	56	*Carn.*	Llandudno	1·24	65
,,	Sherborne St. John	1·23	58	*Angl.*	Llanerchymedd	1·81	76
Herts.	Royston, Therfield Rec.	1·38	62	*I. Man.*	Douglas, Borough Cem.	1·32	55
Bucks.	Slough, Upton	1·69	82	*Wigtown*	Port William, Monreith	2·54	108
Oxford	Oxford, Radcliffe	1·54	69	*Dumf.*	Dumfries, Crichton R.I.	2·77	109
N'hant.	Wellingboro', Swanspool	2·03	97	,,	Eskdalemuir Obsy.	5·19	165
Essex	Shoeburyness	1·06	60	*Roxb.*	Kelso, Floors	1·72	82
,,	Dovercourt	1·02	58	*Peebles*	Stobo Castle	2·82	121
Suffolk	Lowestoft Sec. School	1·73	96	*Berwick*	Marchmont House	2·60	113
,,	Bury St. Ed., Westley H.	1·72	82	*E. Loth.*	North Berwick Res.	2·70	163
Norfolk	Sandringham Ho. Gdns.	2·37	109	*Midl'n.*	Edinburgh, Blackf'd. H.	1·69	85
Wilts.	Bishops Cannings	1·83	76	*Lanark*	Hamilton W. W., T'nhill	1·40	64
Dorset	Creech Grange	1·45	63	*Ayr*	Colmonell, Knockdolian	2·58	102
,,	Beaminster, East St.	·96	42	,,	Glen Afton, Ayr San	3·42	144
Devon	Teignmouth, Den Gdns.	·68	35	*Bute*	Rothesay, Ardencraig	2·65	86
,,	Cullompton	1·33	63	*Argyll*	L. Sunart, Glenborrodale		
,,	Ilfracombe	1·42	66	,,	Poltalloch	3·50	115
,,	Okehampton, Uplands	3·40	123	,,	Inveraray Castle	4·66	118
Cornwall	Bude, School House	1·46	73	,,	Islay, Eallabus	3·19	122
,,	Penzance, Morrab Gdns.	1·36	61	,,	Tiree	2·91	114
,,	St. Austell	1·78	68	*Kinross*	Loch Leven Sluice	2·17	99
,,	Scilly, Tresco Abbey	2·03	117	*Fife*	Leuchars Airfield	1·18	71
Glos.	Cirencester	1·74	73	*Perth*	Loch Dhu		
Salop.	Church Stretton	1·32	52	,,	Crieff, Strathearn Hyd.	2·35	89
,,	Cheswardine Hall	1·76	72	,,	Pitlochry, Fincastle	1·39	67
Worcs.	Malvern, Free Library	2·12	91	*Angus*	Montrose, Sunnyside	1·21	73
Warwick	Birmingham, Edgbaston	2·21	95	*Aberd.*	Braemar		
Leics.	Thornton Reservoir	1·61	75	,,	Dyce, Craibstone	1·80	96
Lincs.	Boston, Skirbeck	1·36	75	,,	Fyvie Castle	2·30	110
,,	Skegness, Marine Gdns.	1·02	57	*Moray*	Gordon Castle	1·97	97
Notts.	Mansfield, Carr Bank			*Nairn*	Nairn, Achareidh		
Derby	Buxton, Terrace Slopes	2·85	89	*Inverness*	Loch Ness, Garthbeg	2·54	111
Ches.	Bidston Observatory	1·36	62	,,	Glenquoich	7·12	145
Lancs.	Manchester, Whit. Park	3·04	115	,,	Fort William, Teviot	5·80	163
,,	Stonyhurst College	3·41	111	,,	Skye, Duntuilm	4·04	155
,,	Squires Gate	1·51	73	*R. & C.*	Tain, Tarlogie House	2·23	121
Yorks.	Wakefield, Clarence Pk.	·92	43	,,	Inverbroom, Glackour	4·12	146
,,	Hull, Pearson Park	1·58	77	,,	Applecross Gardens	4·67	163
,,	Felixkirk, Mt. St. John	1·95	89	,,	Achnashellach	8·02	213
,,	York Museum	1·12	54	,,	Stornoway Airfield	2·62	119
,,	Scarborough	1·53	83	*Suth.*	Loch More, Achfary	8·82	238
,,	Middlesbrough	1·47	78	*Caith.*	Wick Airfield	1·96	109
,,	Baldersdale, Hury Res.	1·53	65	*Shetland*	Lerwick Observatory	4·01	224
Norl'd.	Newcastle, Leazes Pk.	1·35	64	*Ferm.*	Crom Castle	2·35	87
,,	Bellingham, High Green	2·08	90	*Armagh*	Armagh Observatory	2·83	112
,,	Lilburn Tower Gdns.	1·66	80	*Down*	Seaforde	1·95	71
Cumb.	Geltsdale	2·95	109	*Antrim*	Aldergrove Airfield	2·37	98
,,	Keswick, High Hill	2·63	90	,,	Ballymena, Harryville	2·70	93
,,	Ravenglass, The Grove	2·94	113	*L'derry*	Garvagh, Moneydig	2·70	106
Mon.	Abergavenny, Larchfield	1·13	46	,,	Londonderry, Creggan	2·58	92
Glam.	Ystalyfera, Wern House	4·30	114	*Tyrone*	Omagh, Edenfel	3·10	110

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TORNADOES OF MAY 21, 1950

By H. H. LAMB, M.A.

Introductory.—Tornadoes are intense whirls of small diameter in which the inflowing wind rotates (usually cyclonically) and feeds a strong vertical current at the centre, capable of lifting men, beasts and heavy objects, and in which the maximum horizontal velocities may exceed hurricane force. The great wind velocities, the twisting effects associated with the exceptional horizontal gradients of velocity and the extremely localised development of great pressure differences, amounting to an appreciable fraction of normal atmospheric pressure, all combine to make this the most violent of atmospheric disturbances.

For a tornado to occur, conditions favouring the development of violent vertical convection, as in thunderstorms, must exist. Thunderstorms and tornadoes may therefore be regarded as associated phenomena. Further, conditions must enable the development of violent up-currents right down to ground level. For this a system of strongly converging winds is necessary, a system most easily developed where there is a maximum of horizontal shear, and spinning, sometimes at high velocity, can be set off. The development of the strong vertical current at low levels is also favoured by high humidity and a low condensation level. It appears that topographical features may provide the trigger by local sharp accelerations of the horizontal winds as a front or shear line advances.

In America it has been found that only warm sectors of unstable tropical air from the Gulf of Mexico produce tornadoes[1]*, a fact which explains the overwhelming predominance of tornado tracks orientated from south or south-west to north or north-east. In Europe the situations giving rise to tornadoes usually (but not always) involve unstable, warm and moist southerly or south-westerly air streams.

Destructive tornadoes are uncommon in the British Isles though relatively most frequent in the broad English lowlands and river basins. Fifty occurrences have been noted either in the *Meteorological Magazine* or in the publications of the Royal Meteorological Society since 1868, with trails varying in length from a few hundred yards to over a hundred miles, the longer trails being always intermittent. It seems certain, however, that short trails of damage caused by similar phenomena in open country must occur more often than reports are received. The main tornado, formed in Buckinghamshire on May 21, 1950, ranks amongst the three worst in our records of the past 82 years* and its track was amongst the longest recorded here or on the continent of Europe[4].

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*The index numbers refer to the list of references on pp. 255 and 256.

Tornadoes are much more common in the United States, especially in the great plains and in the Mississippi basin. In most years over 100 are reported in the United States[5]. 1949 was a record year with 290 occurrences; of these only about ten per cent., however, did damage equalling or exceeding that caused by the worst English tornadoes. Loss of life is a common accompaniment, and the fact that no human deaths were caused by the Buckinghamshire tornado must be considered fortunate.

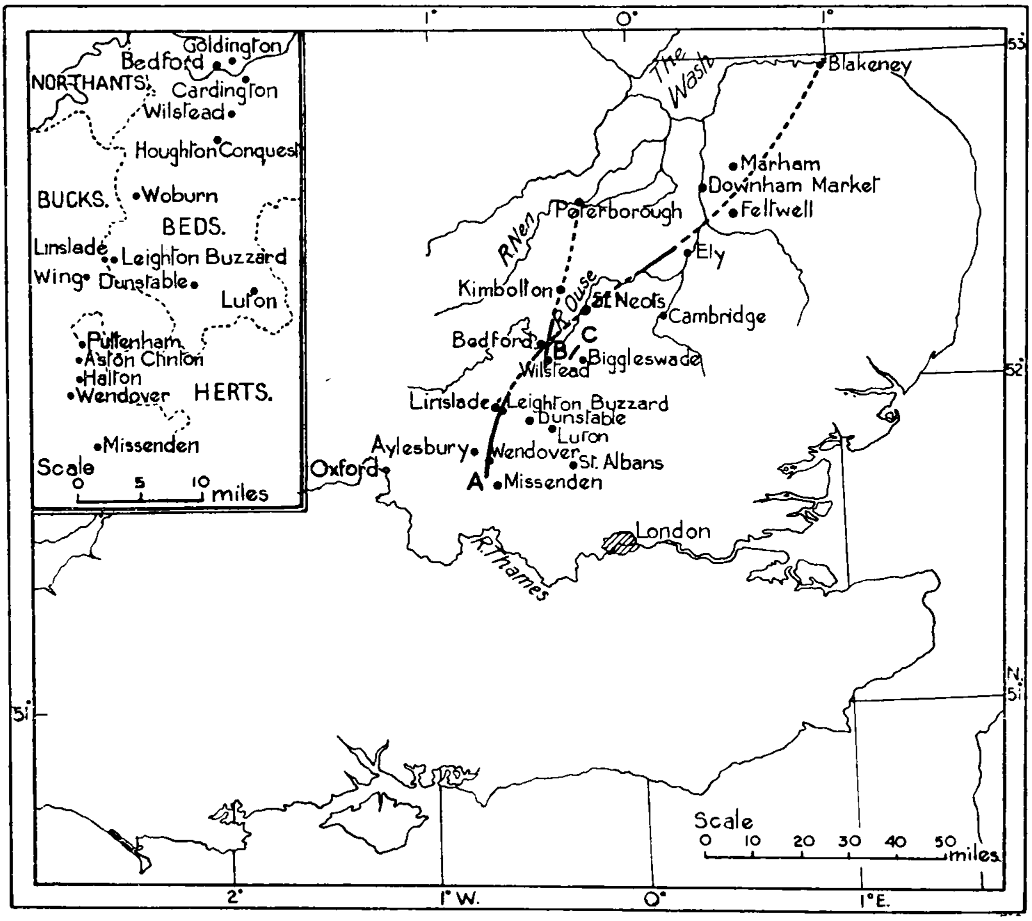
Goldington
Bedford
NORTHANTS.
Cardington
Wilstead
Houghton Conquest
BUCKS.
Woburn
BEDS.
Linslade
Leighton Buzzard
Wing
Dunstable
Luton
Puttenham
Aston Clinton
Halton
Wendover
HERTS.
Missenden
Scale
0
5
10
miles
1°
0°
1°
53°
The Wash
Blakeney
Marham
Downham Market
Feltwell
Peterborough
R. Nen
Ely
Kimbolton
R. Ouse
St. Neots
Cambridge
Bedford
C
B
Wilstead
Biggleswade
52°
Linslade
Leighton Buzzard
Dunstable
Luton
Aylesbury
Wendover
St. Albans
Oxford
A
Missenden
London
R. Thames
N.
51°
51°
Scale
0
10
20
30
40
50
miles
2°
1° W.
0°
1° E.

FIG. 1—TORNADO TRAILS OVER SOUTH-EAST AND EAST ENGLAND, MAY 21, 1950
A = Main tornado; B = Wilstead–Goldington tornado; C = Caldecote tornado

Events of May 21, 1950.—Conditions more or less favourable for tornado formation appear to have existed over a wide area of eastern England on May 21, 1950. Similar incipient circulations in the cloud base were seen by many observers between Buckinghamshire and the East Anglian coast, and, together with the remarkable convergence of the cloud motions feeding into these circulations, constituted a visibly threatening aspect of the thunderstorms from about 1400 G.M.T. onwards. Altogether three tornadoes left trails of damage, though one was short and another mainly in open country; the great bulk of the damage, estimated at over £50,000, was done by the remaining one along a 65-mile track from Wendover to the fens near Ely (Fig. 1).

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*The other comparable cases were on October 19, 1870[2] and October 27, 1913[3].

Losses totalled £25,000 in Linslade, Bucks, alone, where some fifty houses were unroofed and a brick-built bakery demolished (see photograph between pp. 260 and 261). In the country full-grown trees were felled and others had their tops twisted off, trunks up to a yard thick being severed more or less cleanly. Many fruit trees were damaged and at some places whole orchards were uprooted. Farm buildings were shattered and lighter structures (such as chicken coops) and Nissen huts carried away and destroyed. The floor of one hut was left spiked on to the topmost branches of a neighbouring elm. Vehicles, including cars and farm carts with animals in them, were lifted and thrown about. Sheets of corrugated iron were carried distances up to half a mile and killed two cows. Over 500 chickens were lost. Telephone lines and wireless and television aerials were broken and power lines interrupted.

Apart from the Linslade-Leighton Buzzard area the places worst hit by the tornado were Wendover, Halton, Aston Clinton, and Puttenham, the outskirts of Bedford and Sutton near Ely (see photographs facing pp. 253 and 268 and between pp. 260 and 261).

All three tornadoes probably had their origins near the northern edge of the Chiltern Hills, the main one first appearing in the Missenden-Wendover Valley a little before 1600 G.M.T. and suddenly increasing the breadth and scale of its destruction at Wendover where the valley opens on to the Vale of Aylesbury. In a field just south of Wendover full-grown elms and walnut trees were felled over a width of 50 yd. and left lying in all directions. Passing over Wendover town the trail narrowed again, lifting the tiled roofs of old buildings, and after raising a column of water from the canal the tornado proceeded for a mile or so in less violent form. It was regenerated at Halton Camp (see photograph facing p. 252), where the heavy roof of the power station was lifted, and beaten nettles and battered trees registered the full counter-clockwise rotation of the storm. The twisting cloud column was seen to break up as it passed over a close avenue of chestnut trees across its path, and the evidence suggests that a ground whirl somewhat separate from the upper part of the column continued for the next 300 yd. or so.

Approaching Aston Clinton the revolving cloud was first seen 200 ft. clear of the ground, but soon lowered to the downhill slope and began to damage trees and buildings. Here for the first time the path performed several zigzags, influenced apparently by the configuration of dense coppices in the park but never going more than 200 yd. from its main course.

Over the up-slope to the ridge at Wing, some miles further on, the tornado zigzagged rather more, and at one stage broke into three or four columns, which reunited as it surmounted the eastern end of the ridge and bore down upon Linslade with redoubled fury. Even here the trail of damage did not depart more than 400 yd. from the general line.

The trail was in most places only 5–7 yd. wide, but broadened temporarily at Wendover, Linslade, near Bedford and at Sutton to 40 or 50 yd. Objects carried up in the twisting column were, however, strewn over a width of fully 200 yd. in places.

As is usual with tornadoes, all three on this day passed through successive cycles of regeneration and decay, often at about 5-min. intervals. Considerable distances were skipped entirely or passed over with the funnel cloud seen not reaching to ground level.

Nearly all the main bursts of energy occurred just north of a ridge of higher ground. After Linslade which was hit about 1630 G.M.T., the distances skipped became longer, and the tornado was probably tending to weaken as the highest temperatures of the day were past. Nevertheless two major regenerations took place over the low-lying, humid regions near the Ouse at Bedford and as late as 1830 G.M.T. over the fens near Ely.

Apart from these evident ground controls, the tornado travelled at about 24 m.p.h. in agreement with the wind at the 600–700-mb. level* (10,000–14,000 ft.) towards the north-north-east accompanied by a severe thunderstorm. Lightning and hail also caused damage, and took a toll of life amongst men and animals. Individual hailstones over 2 in. in diameter were picked up at two places on the actual track over which the tornado passed, and moderately large hail fell to considerable depths afterwards, especially at places just west of the track. Flooding also interrupted traffic on the Great North Road and on many roads in the Ouse and Nene Valleys and the Vale of Aylesbury.

After the main tornado had been in existence for an hour or so a widening cyclonic circulation was noticeably developing around it, establishing light westerly winds up to 50 miles south of the centre and carrying a sharp clearing front through from west to east; temperature dropped sharply with the heavy rain and hail preceding this front and remained some 10°F. lower than before; the sky cleared. This growing cyclonic circulation seems to have been continuous with that of a small depression in the North Sea next day, reaching Sweden on the 23rd, and travelling with the thermal wind over the centre.

Beyond Ely no further damage was reported, but the funnel cloud was seen at intervals lowering and then withdrawing into the cloud base. Over Feltwell, approaching the escarpment which forms the eastern limit of the fenland, it was broken up into dozens of smaller vortices 1,500 ft. above the ground but later re-formed again and was last seen over the sea off Blakeney, Norfolk. The thunderstorm was severe along this line, especially over the escarpment between Feltwell and Marham.

The subsidiary tornadoes formed 10–20 miles farther east, travelled north-north-east with the wind about the 600-mb. level and never developed a wider circulation. One damaged a few roofs and one tree at Caldecote near Biggleswade, Beds. The other passed along a 6-mile track from Houghton Conquest and Wilstead to Goldington near Bedford doing considerable damage. Near Bedford its track crossed the path of the main tornado, and points south-east of the town felt both. The major one was only 8–10 miles away (south-west) at the time, but no coalescence took place. The subsidiary tornado did no damage north of Goldington parish but the swirling cloud was seen as far north as Kimbolton, Hunts; its progress was accompanied by a distinct maximum of rainfall and other thunderstorm activity which continued to Peterborough, where the fire brigades were at work all night dealing with severe damage caused by flooding and lightning.

Meteorological circumstances.—*In the immediate neighbourhood of the whirl.*—No instrumental records from the immediate path of these tornadoes have come to light, though the Cardington anemometer and barograph were within 1½ miles of the two principal ones and have registered the effects of both (see Fig. 2). More striking tornado barograms are shown by Shaw[6], who

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*See Table I.

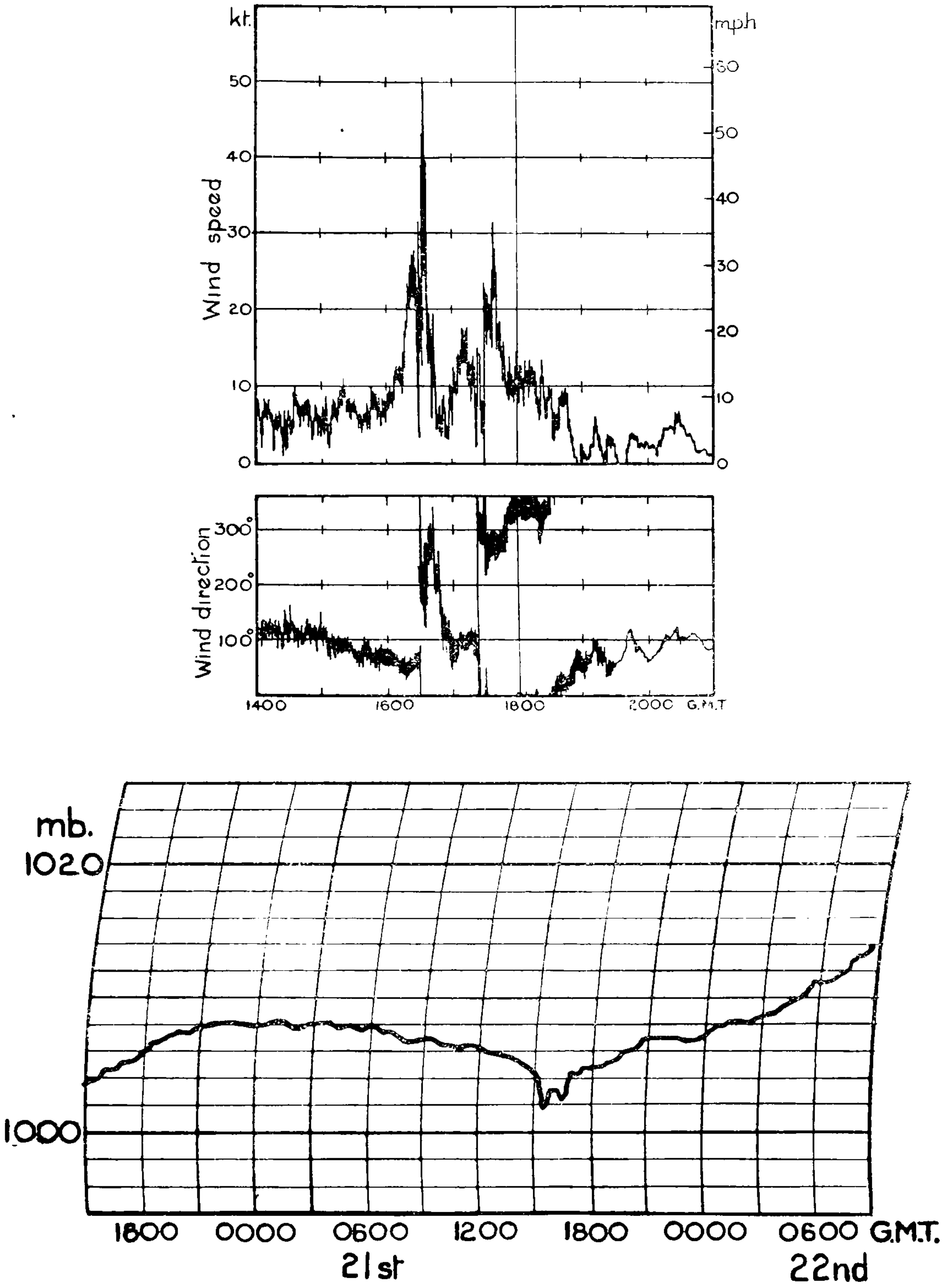


FIG. 2—AUTOGRAPHIC RECORDS FOR CARDINGTON, MAY 21, 1950

The maximum gust of 51 kt. occurred at 1632 as the Wilstead tornado (B on Fig. 1) passed, ¾ mile away. The second maximum at about 1705 is probably the passage of the major tornado (A on Fig. 1) about 1½ miles away, causing structural damage in south Bedford.

The maximum gust of 31–32 kt. at 1740 probably marks the clearing ront.

The barograph clock was nearly ¾-hr. slow.

remarks that " there seems no limit to the possible descent of the pen in the more violent examples . . .". Indeed the adiabatic cooling necessary to bring the cloud to ground level would indicate a pressure fall of at least 20–30 mb.[7]*, and if we accept the height of the unbroken water-column raised in the waterspout as a rough and ready water barometer measuring the pressure difference between the centre and its surroundings pressure may drop 200–300 mb. within a foot or so of the centre. In the present instance the Wilstead tornado raised a water column at Chapel End Farm near Houghton Conquest from a duck-pond between two barns in a peculiarly good position for gauging its height, and the unbroken column reached at least 10 ft., indicating a pressure drop of the order we have supposed.

With pressure profiles of this sort the maximum wind velocities must affect areas of extremely narrow cross-section and become almost meaningless apart from the gradients of velocity involved. The Cardington anemometer recorded about 40 kt. for some minutes around 1630 G.M.T., ¾ mile from the nearest tornado (actually the Wilstead subsidiary) and a maximum gust of 51 kt. The main tornado about 1½ miles away at 1710 G.M.T. only raised the anemometer pen to 15–17 kt. These values are of the same order as the theoretical " gradient " wind, in which friction is ignored and the cyclostrophic term plays a large part. This indicates that velocities of 200–250 kt. might well have been measured near the centre, agreeing with the estimates in various standard works. The most violent damage appears to be done by the great local pressure differences and by twisting. It is mainly lee-side walls and windows which blow out, and the safest position for a man caught by an advancing tornado is said to be to stand facing the wind against a windward-facing wall[8].

The whirl appears to consist of a vortex superimposed on the general air stream with which it travels. In this case therefore the south-westerly winds of its right-hand side would be about 40 kt. stronger than the winds of the other side. Many more trees and objects were battered down by the south-westerly wind than by any other. This is said to be a common feature also of American tornadoes[8].

The general weather situation.—The synoptic situation is best seen from the re-analysed map for 1500 on May 21, just an hour before the main tornado appeared (Fig. 3). The corresponding upper air maps are not reproduced as there is some doubt about the patterns required to fit the Liverpool observations, but the morning map at 700 mb. (see *Daily Aerological Record*) and the actual winds set forth in Table I show that the tornado formed in a region of

TABLE I—OBSERVED UPPER WINDS

Time of ascent	Pressure level	Observed upper winds				Tornado area. Vector mean of Larkhill and Downham Market upper winds	
		Larkhill		Downham Market			
G.M.T.	mb.	°true	kt.	°true	kt.	°true	kt.
1400 (before tornado)	500	213	25	200	32	207	28
	700	168	34	201	32	185	33
	850	133	19	194	25	172	21
	950	123	15	155	15	139	14
2000 (after tornado)	500	185	36	192	31	189	33
	700	194	25	205	30	201	27
	850	205	21	228	30	216	25
	950	228	12	277	20	259	15

* Båth also uses this approach.

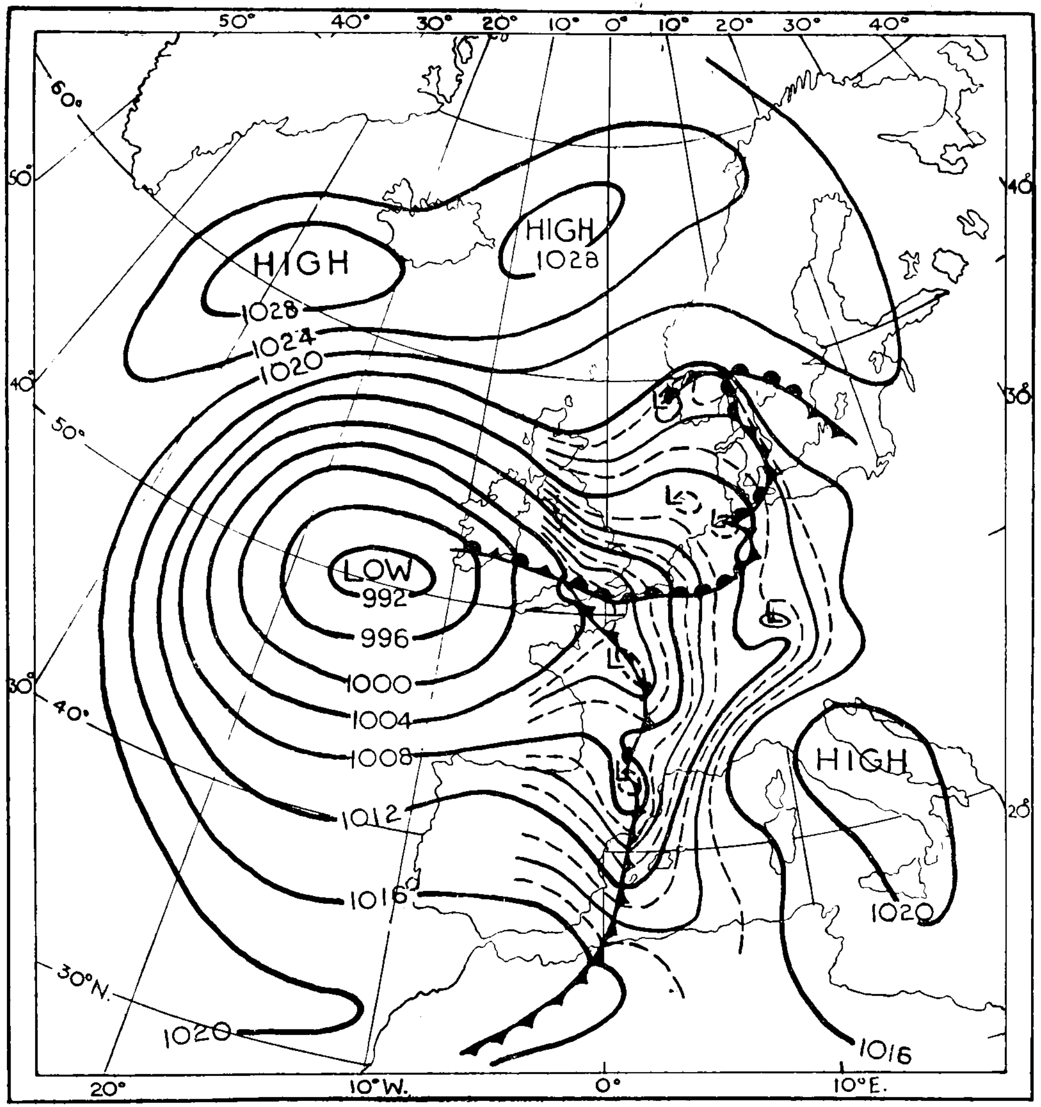

50°
40°
30°
20°
10°
0°
10°
20°
30°
40°
60°
50°
40°
30°
HIGH
1028
HIGH
1028
1024
1020
LOW
992
996
1000
1004
1008
1012
1016
1020
HIGH
1020
1016
L
40°
30°
20°
30°N.
20°
10°W.
0°
10°E.

FIG. 3—SEA-LEVEL SYNOPTIC CHART, 1500, MAY 21, 1950

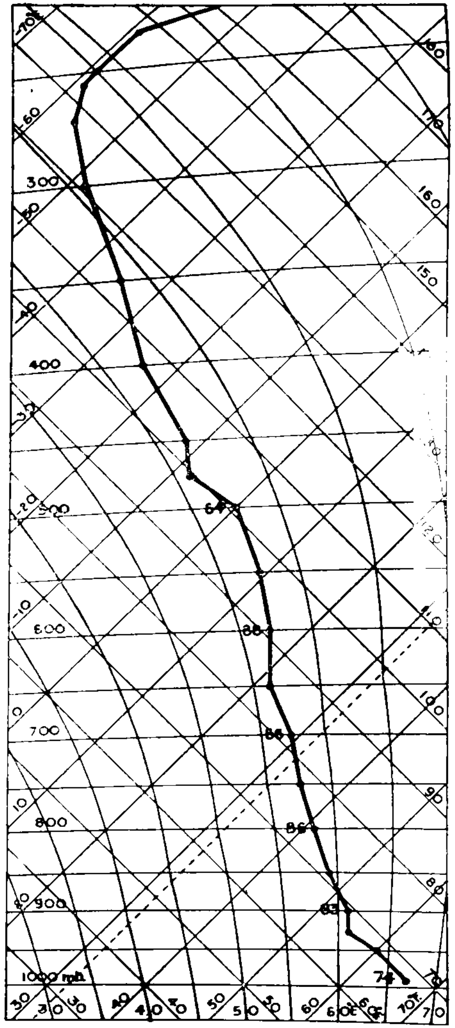


FIG. 4—LARKHILL UPPER AIR TEMPERATURES, 1500, MAY 21, 1950
Humidities are indicated in bold figures

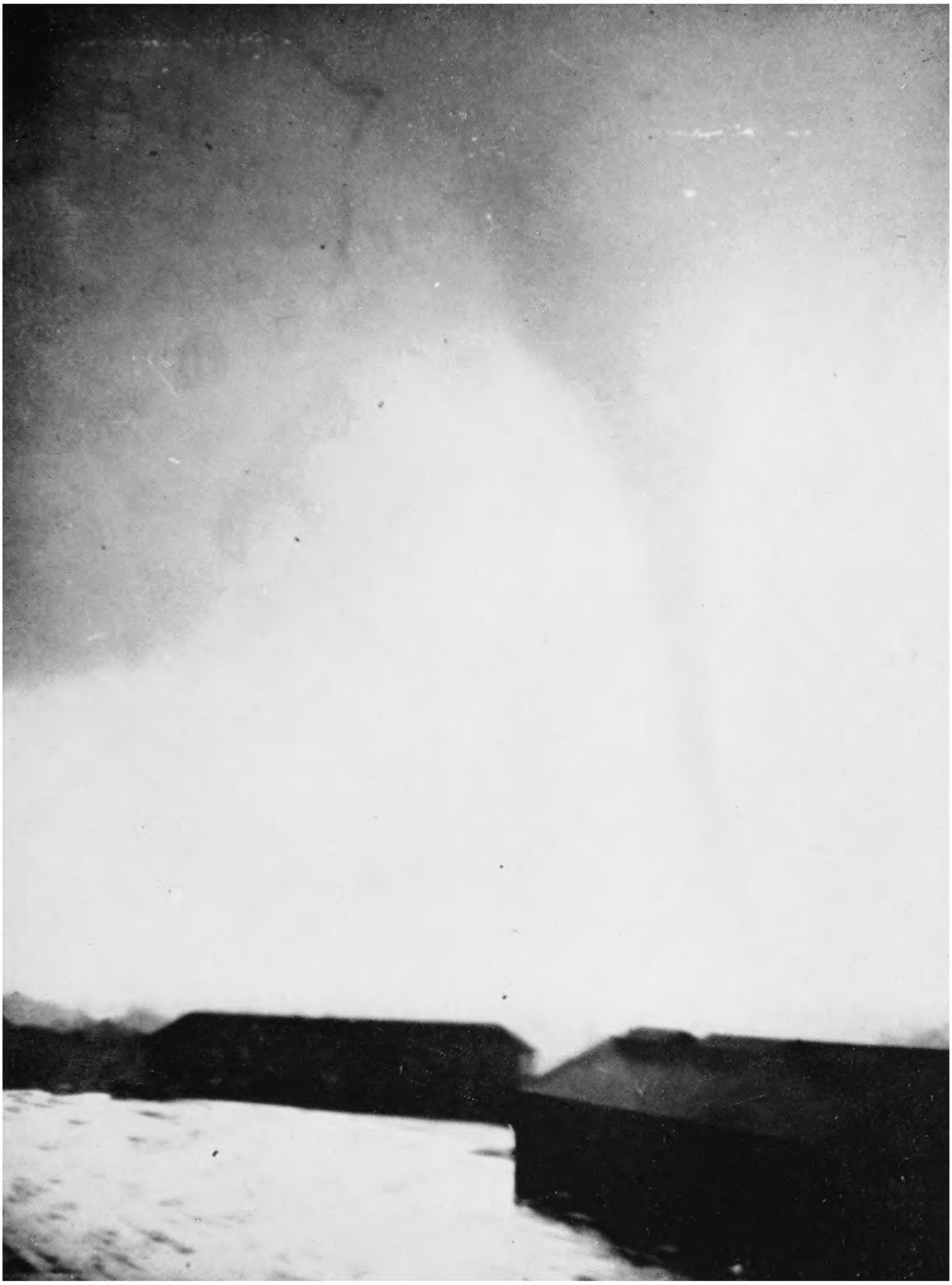
diffluent flow and travelled with the stream at about 10,000 ft. over the centre: similar winds may have prevailed over the region in question right down to the frontal surface about 950 mb. (2,000 ft.).

The tephigrams (see Fig. 4) indicated instability for saturated air in the warm air mass, which reached the ground at Larkhill in the warm-sector tip for a short time about the afternoon ascent with temperatures just approaching 70°F. and which was over-running the tornado area where maxima of 64°F. were only briefly attained. Cumulonimbus cloud development could, and presumably did, proceed to the tropopause ; though this was at only 32,000–35,000 ft., distinctly lower than the extreme values in some other situations in recent years in which severe thunderstorms drifted up from the south.

It is clear that the extreme conditions on this occasion must rather be related to the low level at which great instability and vertical currents of saturated air were occurring and to other features such as the horizontal fields of wind and temperature. The frontal structure was not easy to follow, and to discover a significant association between it and the tornado requires exceptionally close analysis. We note, however, that the thunderstorm in which the main tornado occurred was located over a warm-front surface within 50–100 miles north-east of its point of occlusion. A group or line of thunderstorms about this distance ahead of the cold front was first located by " sferic " plots over the English Channel about midday. Vertical cross-section analysis (not reproduced) shows that the warm-front surface was very low over the Chiltern Hills where the tornado broke out; at points southward the frontal surface had been almost obliterated by ground heating and the front was very hard to place at many points along its length. Nevertheless it was essentially out of this front that the new cold-front clearing line was created—see Fig. 5.

The warm air mass in the warm sector was unstable African tropical air which seems to have come in about 30 hours from Tunisia across the Mediterranean and over or past the eastern end of the Pyrenees to the tornado area in south-east England. Moisture would have been acquired over the Mediterranean and by evaporation over France with much vertical exchange by convective activity both before and after crossing the mountains of France and Spain. As is often the case in similar synoptic situations troughs of low pressure early became noticeable within the warm sector over north-east Spain on the 20th, probably due to lee effect and thermal factors. By the afternoon of the 21st many troughs and minor circulations had developed within the warm sector over France and Germany and on both fronts, and might be regarded as a characteristic of the air stream. (By destroying the even alignment of the fronts these circulations made the frontal analysis more difficult.) The historical cold front from the Atlantic, however, advanced fairly regularly and at very slightly over gradient speed until after 1500 on the 21st, when it began to be replaced as the main cold front by a secondary cold front some 50 miles in its rear.

The broad weather situation was frontogenetic, in that the col over the North Sea and Baltic was maintaining a strong thermal gradient from southern England to Sweden. Yet at the same time the vertical instability of the principal air masses and strong convection was always tending to produce mixing, and the various individual frontal lines were therefore liable to be obliterated and replaced by others within 100 miles or so. The trailing occlusion



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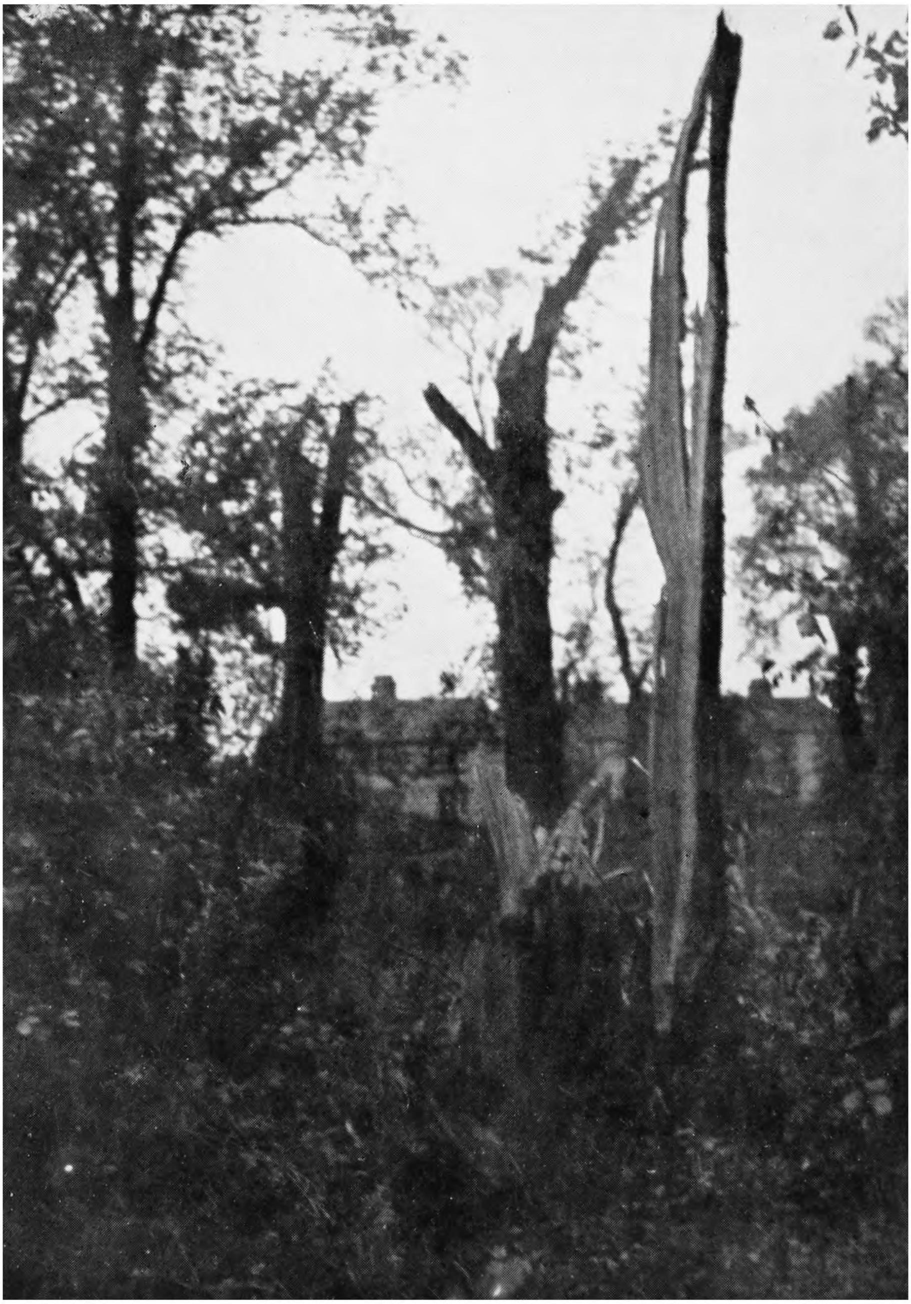
THE MAIN TORNADO APPROACHING HALTON R.A.F. STATION

The rotating funnel cloud was just lowering to the earth when the picture was taken and within the next few minutes a heavy roof in its path was lifted.

(see p. 247)



Reproduced by courtesy of H. H. Lamb

TORN AND BROKEN TREES AT SUTTON, ELY
The trunk in the foreground was 34 in. in diameter
(see p. 247)

of the depression over Norway (shown on the *Daily Weather Report*) or its associated upper front (still partly traceable on the vertical cross-sections over England) seems to have set off the first thunderstorms over southern England on the morning of the 21st; this occlusion line was really obliterated by afternoon, though a surviving portion traceable over East Anglia and acting rather as a warm front is indicated on Fig. 5. The main warm front itself was hardly traceable after the appearance of the tornado which swept part of the front back and generated therefrom a cold front in a new orientation. The exact position of this new front may have been affected by the cooling produced by heavy rainfall along the path of the thunderstorm with which the tornado was associated (see the rainfall map, Fig. 6, which betrays the tracks of the two main tornadoes). At Dunstable, for instance, 10 mm. of rain fell in ten minutes and the thermogram shows a temperature drop of 10°F. with the onset of the hail. Nevertheless, this front merely represents a new configuration and a sharpened state of the boundary between the cool air from the North Sea and the warm air streams from the south and south-west.

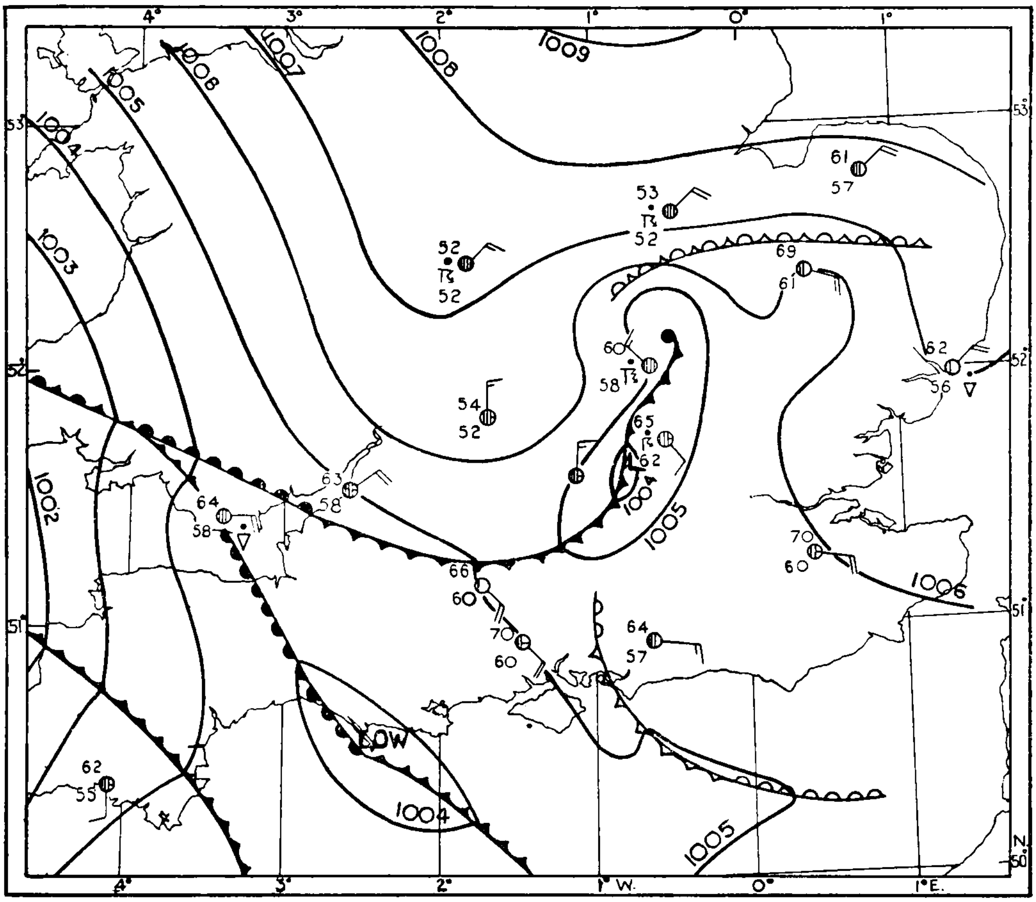


FIG. 5—SEA-LEVEL SYNOPTIC CHART, 1700, MAY 21, 1950

On the 20th thermal " lows " had developed over southern England and Ireland. By the 21st, however, the general pressure gradient had increased, as the main Atlantic low moved northwards from the Portuguese coast to a point near 50°N. off south-west Ireland; on this day, therefore, it was only over eastern England, nearest the col over the North Sea, that a thermal trough and later a thermal low could develop, appearing first about 1400 G.M.T. between Cambridge and London as a small feature seen only on the largest-scale maps. In the trough the preliminary thunderstorms became severe, and as pressure on the approaching thundery warm front became lowest at the point nearest this trough it may actually have initiated a deformation which aggravated the thunderstorms over this part of the frontal surface where the tornado developed and which produced the orientation of the new clearing front. The shear between the surface easterly current and the over-running warm air, already indicated by the winds tabulated in Table I, was progressively increased by this preliminary trough diverting the surface winds over Buckinghamshire gradually to northerly. The surface current from this direction came abruptly into play in the neighbourhood of the northern face of the Chiltern Hills.

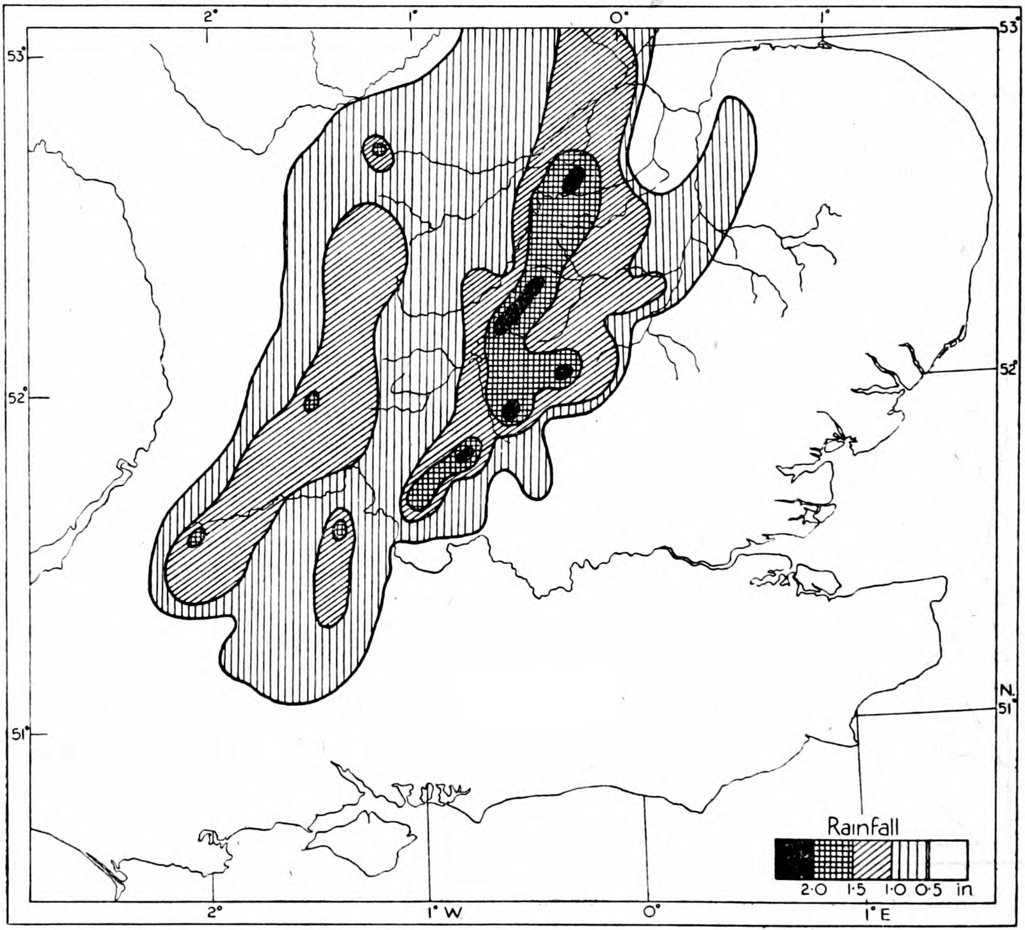
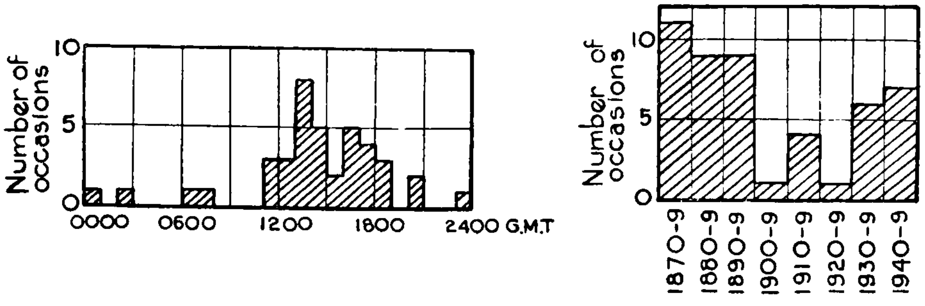


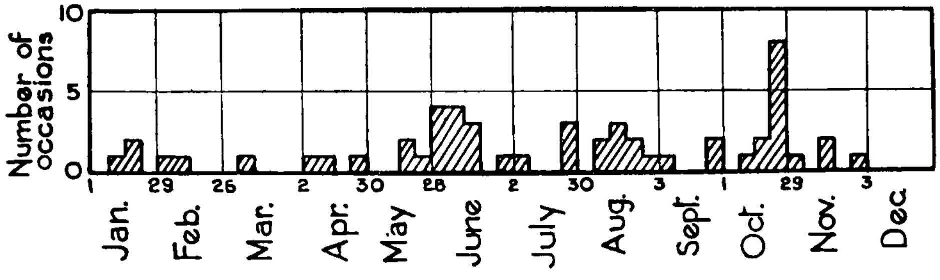
FIG. 6—RAINFALL DURING THE 24 HR. COMMENCING 0900, MAY 21, 1950

The isochrones of the clearing front following the tornado show an initial discontinuity with those of the historical (*i.e.* Atlantic) cold front farther west which can be explained in this way. By next day over the Low Countries, however, the two had probably amalgamated.

The incidence of tornadoes in the British Isles.—Apart from the geographical distribution to which we have referred the fifty cases of destructive tornadoes since 1868 have been examined to find their diurnal, annual and decadal incidence (see Fig. 7) and the accompanying weather situations.



(*a*) Diurnal incidence (*b*) Decadal frequency



(*c*) Weekly incidence (annual trend)

FIG. 7—DIURNAL, SECULAR AND ANNUAL TRENDS OF THE OCCURRENCE O DESTRUCTIVE TORNADOES IN THE BRITISH ISLES, 1868-1950

The " number of occasions " refers to total occurrences between 1868 and 1950

The decadal distribution shows a marked minimum frequency in the years 1900–29, when the general westerlies are believed to have been most prevalent, followed by greater frequency again in recent years. The annual distribution shows that destructive tornadoes can occur in any month*, but are most common in October; no less than eight of the fifty having occurred in the week October 23–29 associated with the best known cyclonic singularity of the year. The other main groupings are about the onset of the European summer monsoon (late May to mid June) and about the time of maximum summer thundery cyclonic situations (late July to mid August)[9]. The diurnal range of frequency shows the expected afternoon and early evening maximum associated with the peak of instability in the lowest air layers.

Examination of the general weather situations showed that most cases were frontal, especially associated with cold fronts and warm sector tips, though a proportion as in the present case showed no very obvious frontal association or formed in thunderstorms on over-running frontal surfaces, particularly near the warm-sector tip aloft. All the winter cases (November–March) were associated with general gales and considerable shear, those in the other months were much more variable in these respects. One case (August 21, 1889, in Shropshire) occurred in an unstable north-westerly current of gale force, but with no apparent frontal structure, coming over the mountains of Wales. In every case the situation is believed to have shown cyclonic curvature or cyclonic shear at the edge of a strong air stream over the region affected.

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*None were reported in December, but there was one on November 30.

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WHIRLWIND AT SHOEBURYNESS

By L. G. HEMENS, B.Sc.

At about 1415 G.M.T. on Thursday, October 20, 1949, Shoeburyness was visited by a whirlwind. Mr. Whitaker, who happened to be outside his office at the time, said that while watching what appeared to be a frontal cloud he heard a muffled sound like distant thunder or an explosion, and on turning to the south-west saw that at a distance of about 1,000 yd. the air was filled to a considerable height with leaves, twigs and similar light debris swirling violently as though after a large but smokeless explosion. He called out two other observers, Messrs. Dunning and Chester, who saw the subsequent events with him. Almost at once the wind increased to gale force, torrential rain began to fall, and the debris, now quite dense and only a few hundred yards away, was travelling towards them from a south-westerly direction and was observed to be rotating from left to right, *i.e.* counter-clockwise. The disturbance very quickly arrived where they were standing. Tall trees in leaf were bent over and thrashed about wildly, and one or two broke. These trees had trunks about 1 ft. in diameter and were about 30 ft. high in a row across the path of the disturbance. A large corrugated-iron roof, held fast at both ends on a nearby shed, billowed up and down like a shaken sheet at a rate of about two vibrations per second. The shed was about 40 ft. by 20 ft. with one side open to the wind, and it was only about 20 yd. away from the observers, looking south-west, who were now standing in an opening of another three-walled shed, the roof of which, fortunately, was more secure. The air was filled with flying debris, gravel from road surfaces and large driving raindrops, all flying past at high speed, and with this there was a continuous loud rushing noise, loud enough to drown the noise of the flapping corrugated-iron roof and the breaking trees. About 30 yd. to the north-east from where they were standing, a large gabled wooden roof was ripped off a brick building and scattered in portions about 40 yd. down wind in a north-easterly direction; one portion was precariously balanced for a time against the chimney stack of an adjacent small building. This was neither seen nor heard while it was happening as the attention of the observers was held in the direction from which the debris was coming. The disturbance was all over in about a minute and the heavy rain ceased almost at the same time. The damage was confined to a narrow track about 100 yd. wide or less.

Damage was done at other places on the track of the disturbance, more especially to trees, light structures and temporary buildings, and there was considerable danger from flying debris and light articles of all sorts, such as sheets of corrugated iron, or gravel, lifted by the wind and carried along at high speed in the wind.

The track of the damage shows that the whirlwind followed an almost straight path although there is evidence of some sinuosity. The direction of travel was from 235° true towards 55° true. The path of the whirlwind is shown in Fig. 1. No estimate could be made of the speed of travel. There is no evidence of how long it was in existence before entering the Shoeburyness area from the Thames Estuary nor of how long it continued after it was last observed from Havengore travelling up the coast towards Foulness.

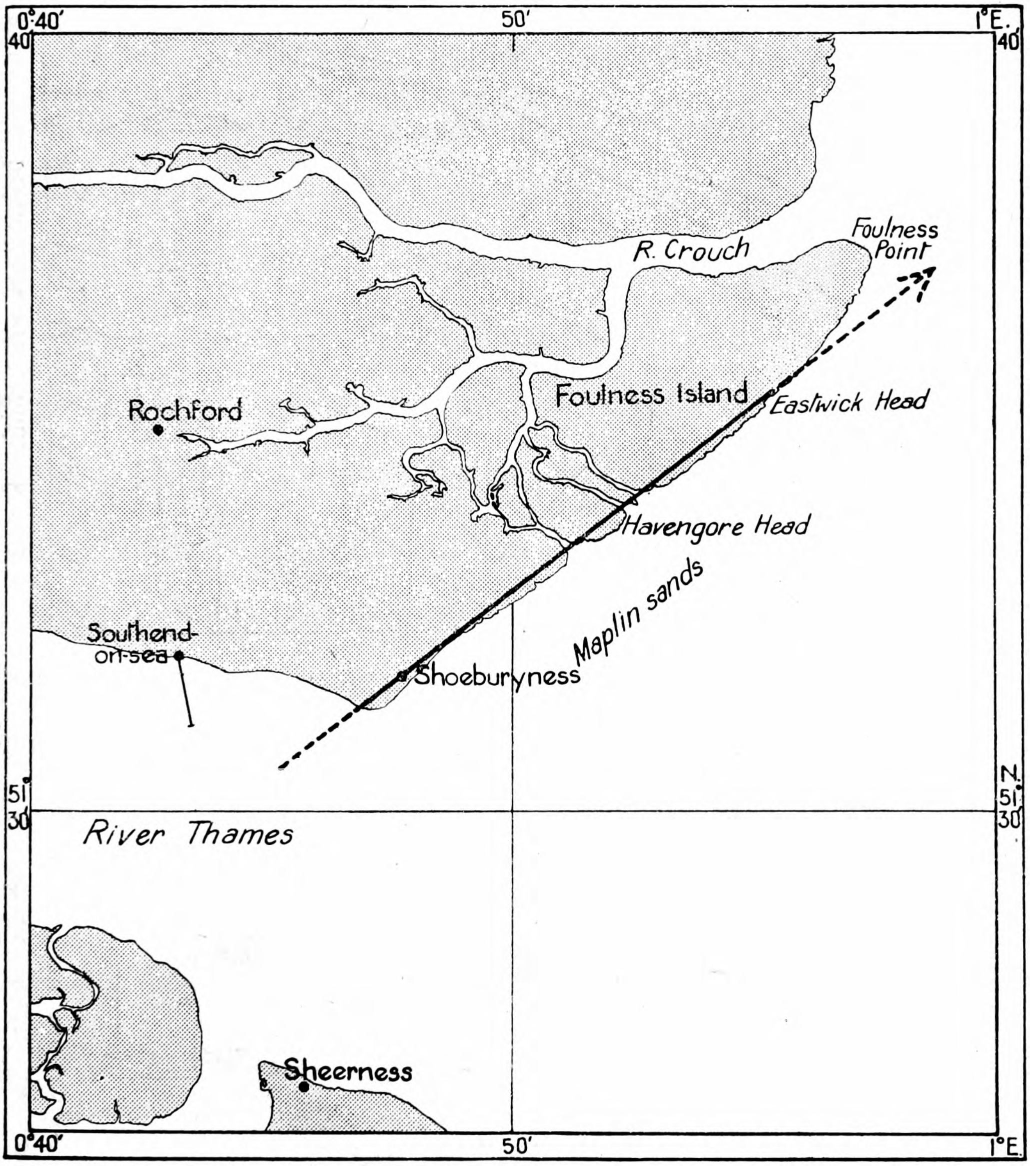
0°40′
50′
1°E.
40
40
R. Crouch
Foulness Point
Foulness Island
Eastwick Head
Rochford
Havengore Head
Maplin sands
Southend-on-sea
Shoeburyness
51°
30
N.
51°
30
River Thames
Sheerness
0°40′
50′
1°E.

FIG. 1—PATH OF THE WHIRLWIND, OCTOBER 20, 1949

Records of the wind velocity are shown on the anemogram for the day from the Dines pressure-tube anemograph on top of the conning tower (effective height 89 ft.) adjacent to the north-east end of the central office building and situated on the south-east edge of the track of the damage (see Fig. 2). The

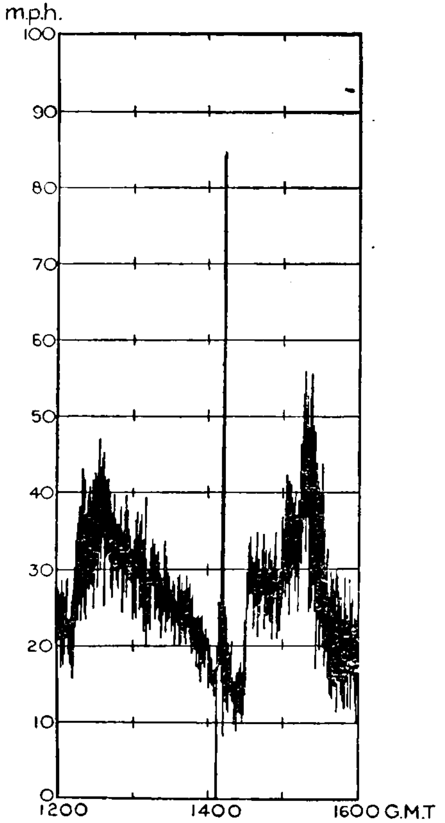

FIG. 2—AUTOGRAPHIC RECORD OF WIND SPEED AT SHOEBURYNESS, OCTOBER 20, 1949

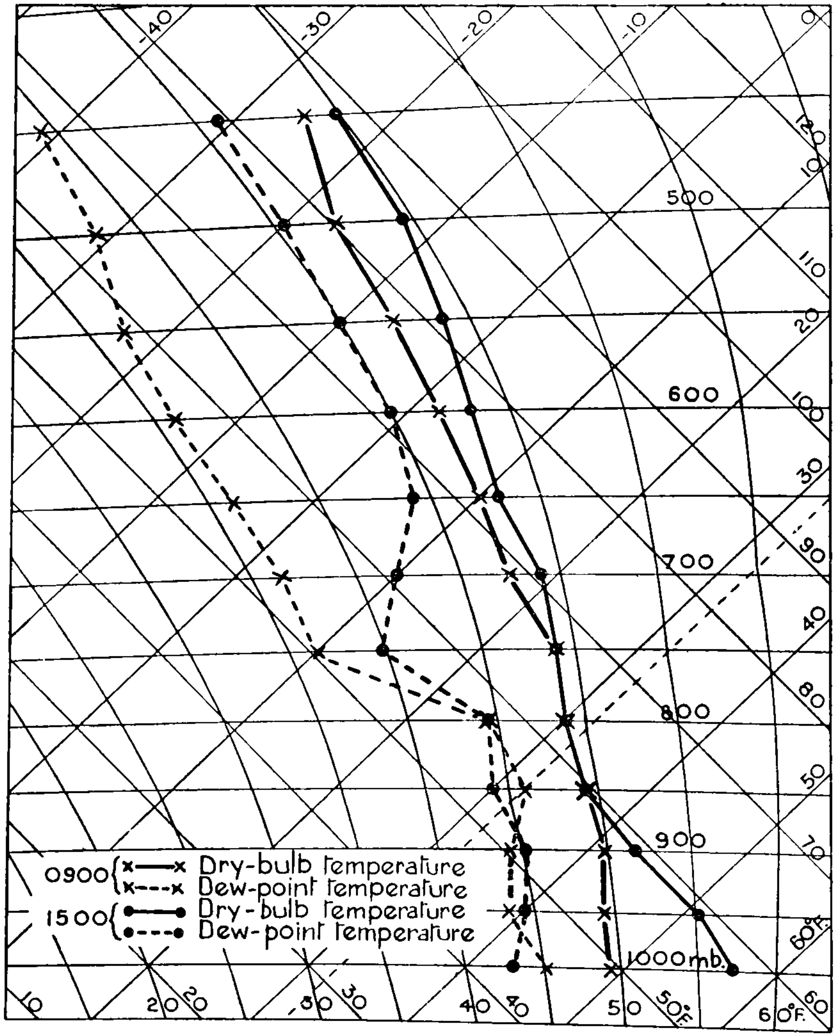

FIG. 3—UPPER AIR SOUNDINGS, DOWNHAM MARKET, OCTOBER 20, 1949

anemograph is an electrical distant recorder. The direction unit was, however, defective and the direction trace is unreliable, although the velocity trace on the distant record is good. The trace accompanying this article is the record from the clock-drum on the float chamber housed at the top of the tower. The interesting feature of the record is that it shows that the wind during the disturbance consisted practically of a single gust rising suddenly to 85 m.p.h. from a mean wind speed of about 16 m.p.h. and dropping equally suddenly back again to about 20 m.p.h. As regards the direction of the wind, the general impression amongst observers is that the general wind direction was from SW. up to the time of the gust, that it then veered to about W. for about 20 min., and subsequently backed again to SW. No information is available as to any large and rapid changes of direction during the actual passage of the gust, due to vortical motion, but the impression is that the wind which did the damage was travelling from SW. in much the same direction as the direction of travel of the disturbance itself. Another feature of the velocity record is that the disturbance occurred in the lull between two squalls, the mean wind in the first reaching a maximum approaching gale force about 1½ hr. before the whirlwind and in the second a maximum above gale force about 1 hr. after the whirlwind.

The synoptic charts for the day show that there was a strong, large-scale circulation of polar air around an extremely large low-pressure system with a family of three centres, one south of Iceland, one between Iceland and Norway, and the third over Lapland. Polar air from the north of the centres extended in a wide sweep over the Atlantic and penetrated as far south as lat. 40°N. before turning north-eastwards towards the British Isles and north-west Europe. Trailing cold fronts were indicated along the southern fringe of the low-pressure area.

The morning at Shoeburyness was mild, and there was continuous sunshine up to about 1230 G.M.T. with a wind of about 15–20 m.p.h. from SW. and about 1 okta of cloud, a few scattered showers and very good visibility. The cloud increased to 3 oktas about midday and there was a temporary increase of wind to about 35 m.p.h. from SW. (maximum gust 47 m.p.h.) at about 1230 with a slight shower. The wind decreased slowly to 16 m.p.h. from SW. by 1400 and the cloud increased to 7 oktas, cumulonimbus, fractocumulus, altocumulus and altostratus. A few minutes before the passage of the whirlwind and within a mile in advance of it, a roll cloud was observed below and attached to the leading edge of a cumulonimbus cloud and extending broadside across the wind. The whirlwind passed at about 1415, and a later report from an observer in an open situation farther up the coast described it as a vertical column of leaves and debris extending upwards and merging into a small downward bulge of cloud lower than the rest of the clouds. After a lull from the W. for about 20 min. after the whirlwind, the wind rose from SW. and increased to a squall of about 45 m.p.h. (maximum gust 56 m.p.h.) at about 1510 with considerable rain and some thunder. Subsequently, for the rest of the day weather was overcast with intermittent light, moderate and heavy showers, visibility very good and the mean wind continuing for some hours between 20 and 30 m.p.h. from SW. and decreasing slowly towards midnight. There were reports of heavy rain and flooding at Rochford and Hockley about 5–8 miles to the north-west of Shoeburyness but no times or details are available.

During the passage of the disturbance the barograph in the meteorological staff office recorded a fall of 4 mb. and a rise of the same amount immediately after, the upstroke on the trace being superimposed on the downstroke. It is doubtful, however, to what extent this fluctuation of pressure is an indication of the fluctuation of static pressure in the vortex. The pressure and suction effects on the windward and lee sides of the building, due to a wind gust of 85 m.p.h. would be considerable, and the reduction of pressure on the lee side may have been communicated inside the room through an open door or window. The barograph also shows small rapid changes of pressure of about 1 mb. associated with the squall which occurred after the whirlwind.

The temperature and humidity records from the instruments exposed under standard conditions on the north-west edge of the track of the damage, and from the instruments on top of the conning tower, do not show any noteworthy change of temperature during the passage of the disturbance. The instruments, however, are rather sluggish. After the passage of the squall at about 1530 there was a fall of temperature of about 4°F. in half an hour. The relative humidity, which had been steadily increasing before the disturbance, increased abruptly from about 80 to 85 per cent. at the time of the disturbance, probably due to the rain.

The profiles of temperature and dew point aloft at Downham Market at 0900 and 1500 are shown in the accompanying tephigram (Fig. 3). At 0900 there was a layer of moist air up to about 7,000 ft. with a lapse rate about or slightly more than the saturated adiabatic. Above this the air was very dry with a lapse rate greater than the saturated adiabatic, there being a sharp discontinuity of the dew point at about 7,000 ft. At 1500 the temperature near the surface had risen about 8°F. and the lapse rate was near the dry adiabatic up to about 4,000 ft., above which the lapse rate was about the saturated adiabatic, and the dew point was very much higher than at 0900.

It is evident that the disturbance was a whirlwind of the tornado type. The cumulonimbus clouds, thundery showers, squalls and the Downham Market temperature and humidity profiles provide ample evidence of the instability associated with tornadoes, and in this connexion the presence of a thick layer of moist air below dry air is noteworthy. The presence of a quasi-stationary cold front in the vicinity, which also appears to be a necessary condition, is probable but less certain. The occurrence of the whirlwind in the region between two squalls of the type more usually associated with unstable moist air may be worthy of note.

ABSOLUTE DROUGHTS OF AUGUST 1947

By J. GLASSPOOLE, M.Sc., Ph.D and H. ROWSELL, B.Sc.

The note on absolute droughts during the period 1906–40, prepared during the war but not published until September 1947*, appeared immediately following one of the most widespread droughts on record. It is shown in *British Rainfall* 1947, that only 4 of the 82 representative stations selected to cover Great Britain and Northern Ireland failed to record an absolute drought between July 29 and September 16. This drought was sufficiently unprecedented, from a number of aspects, to warrant further investigation, and all the daily returns received by the British Rainfall Organization, Meteorological Office, have now been examined.

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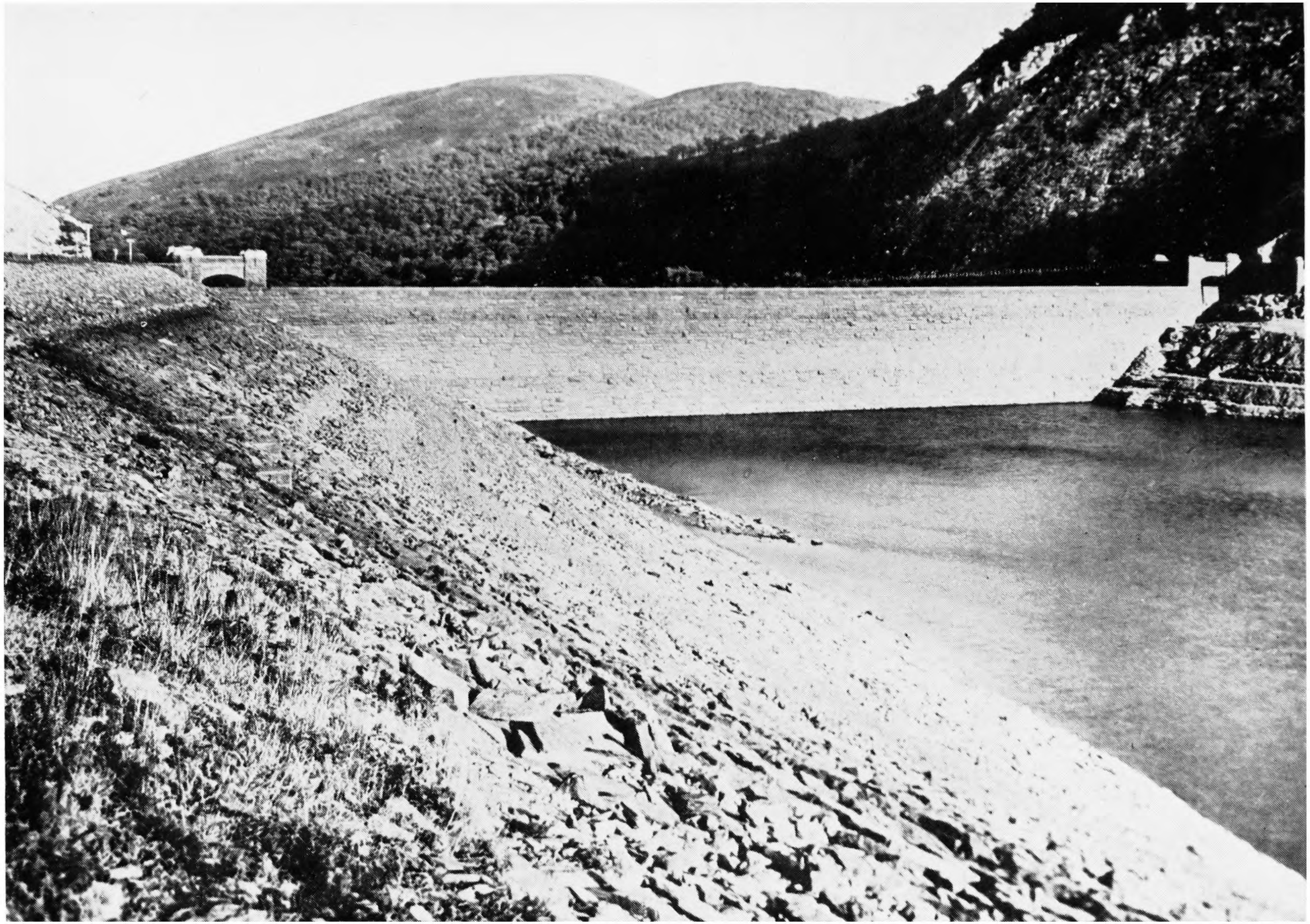
*GLASSPOOLE, J. and ROWSELL, H.; Absolute droughts and partial droughts over the British Isles, 1906–40. *Met. Mag. London*, **76**, 1947, p. 201.

[*To face p.* 260



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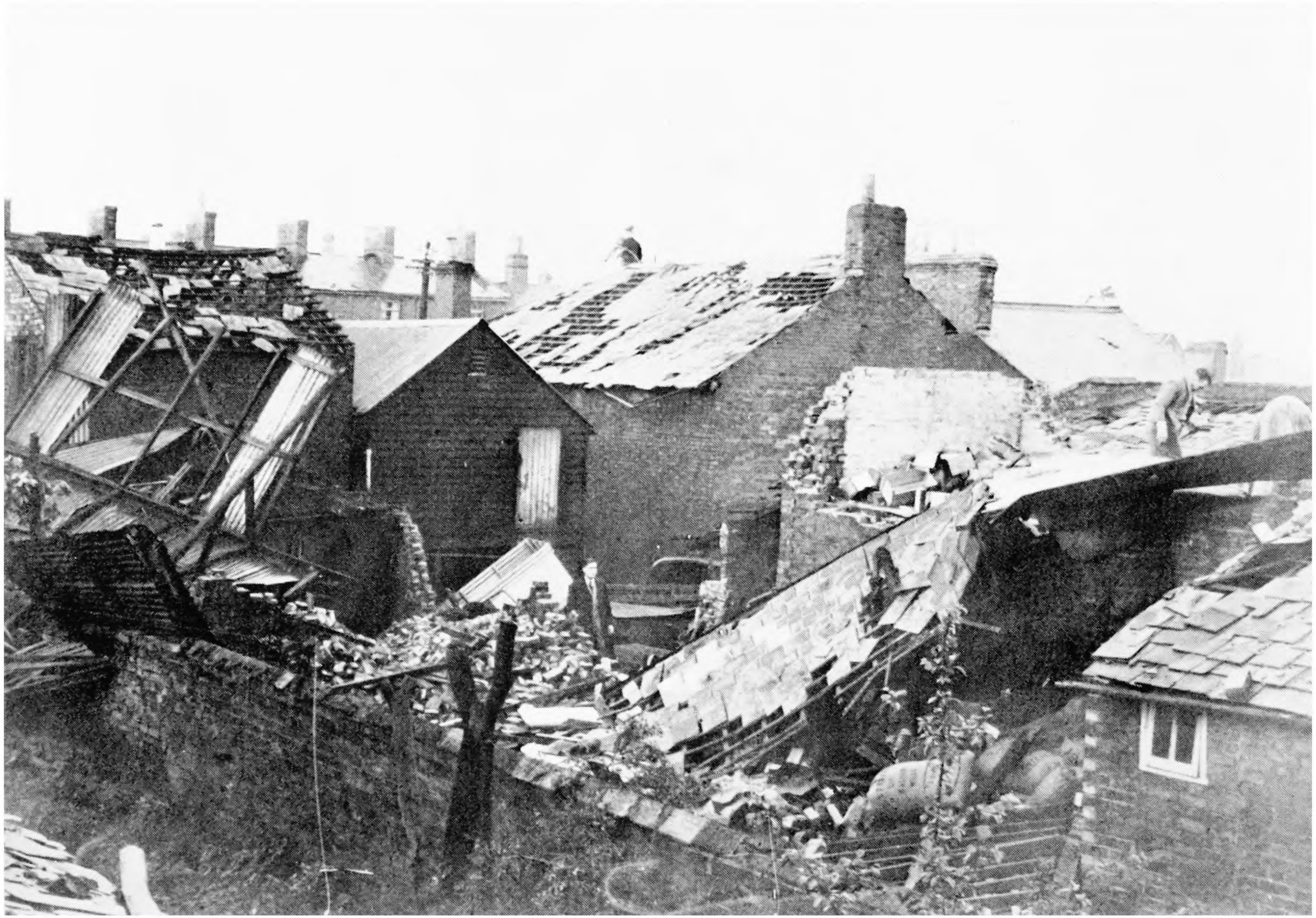
UP-STREAM FACE OF THE MAIN CABAN DAM, RHAYADER WATERWORKS



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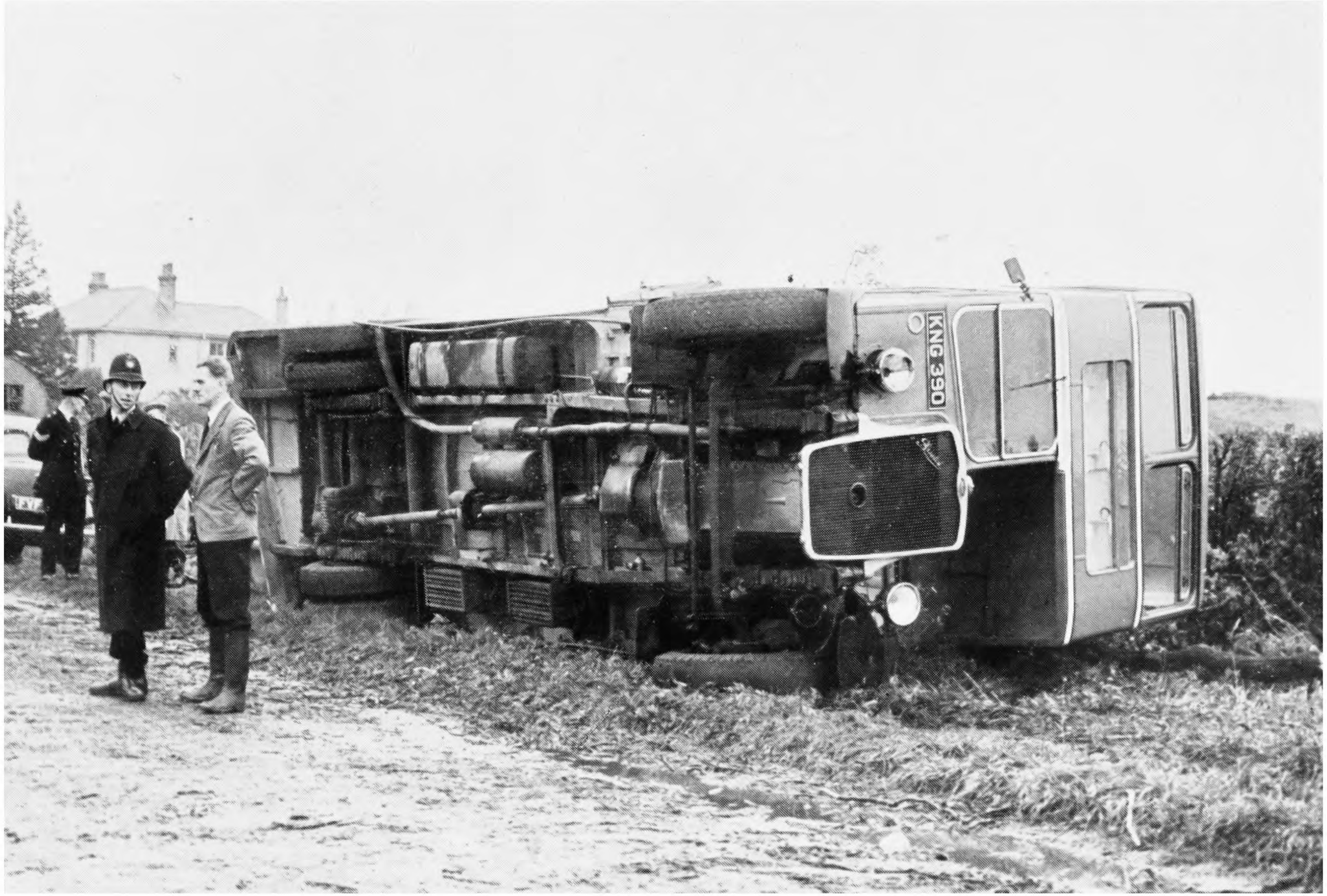
SCENES OF HAVOC AT LINSLADE

(see p. 247)



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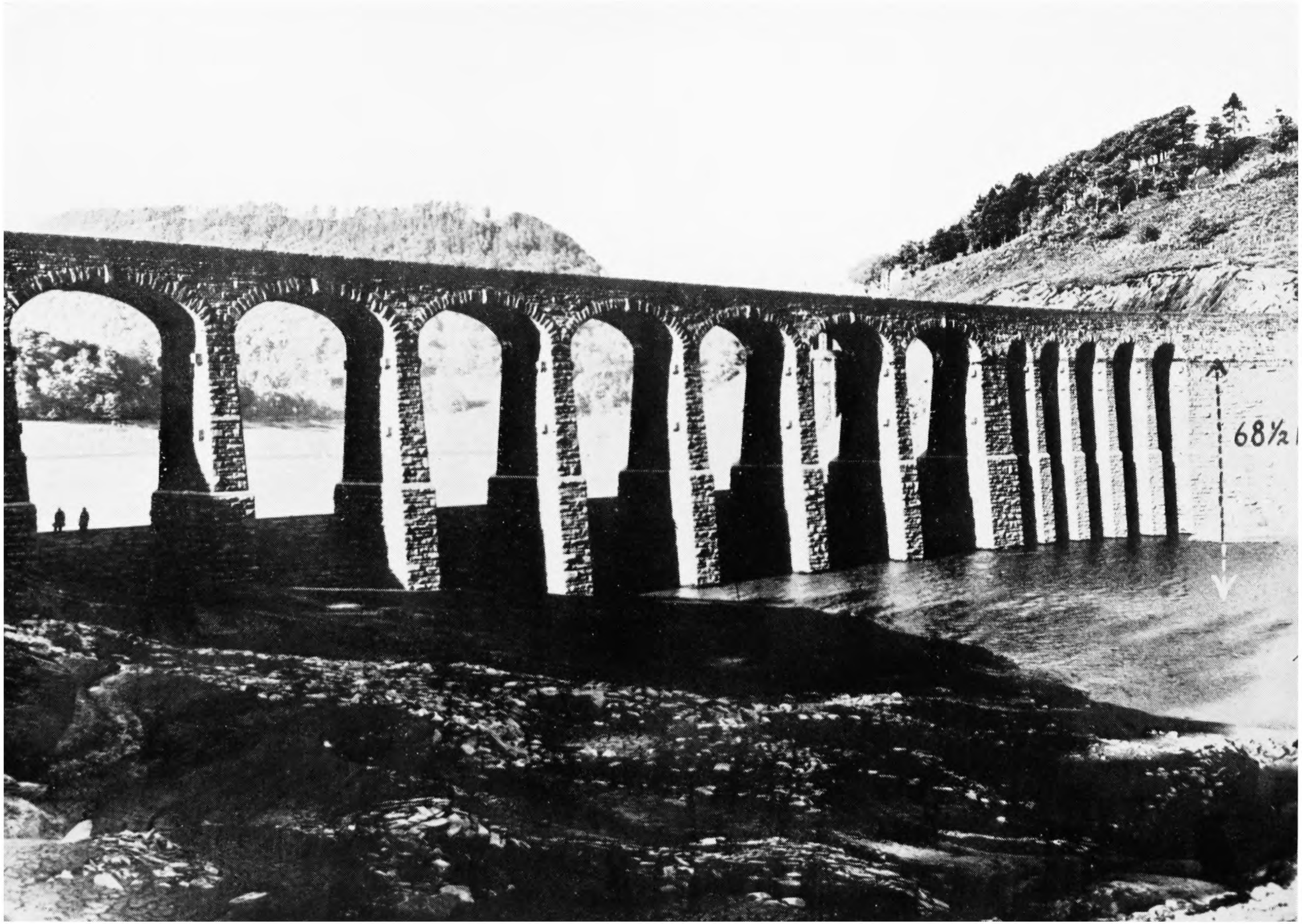
OVERTURNED BUS AT SUTTON, ELY

The bus fell on grass and only one headlamp and one window were damaged.

(see p. 247)

[*To face p.* 261]



Reproduced by courtesy of the Water Department. City of Birmingham

CAREG DDU VIADUCT, SHOWING EFFECTS OF DROUGHT

The map, Fig. 1, shows the greatest number of consecutive days without measurable rain within the period July 29–September 16. It will be seen that only small areas failed to record an absolute drought during this period. (An absolute drought is defined as a period of at least 15 consecutive days, to none of which is credited 0·01 in. of rain or more.) These areas were confined to the neighbourhood of Tavistock, central and north Wales, part of the Cheviots, the west of Co. Tyrone, Skye, the Isle of Lewis, Fortrose, Strathpeffer, Sutherland and the west coast of Ross. No other absolute drought on record covered so large a part of the country, even during the famous dry year of 1887, and the extent of the area with more than 30 days is also unprecedented.

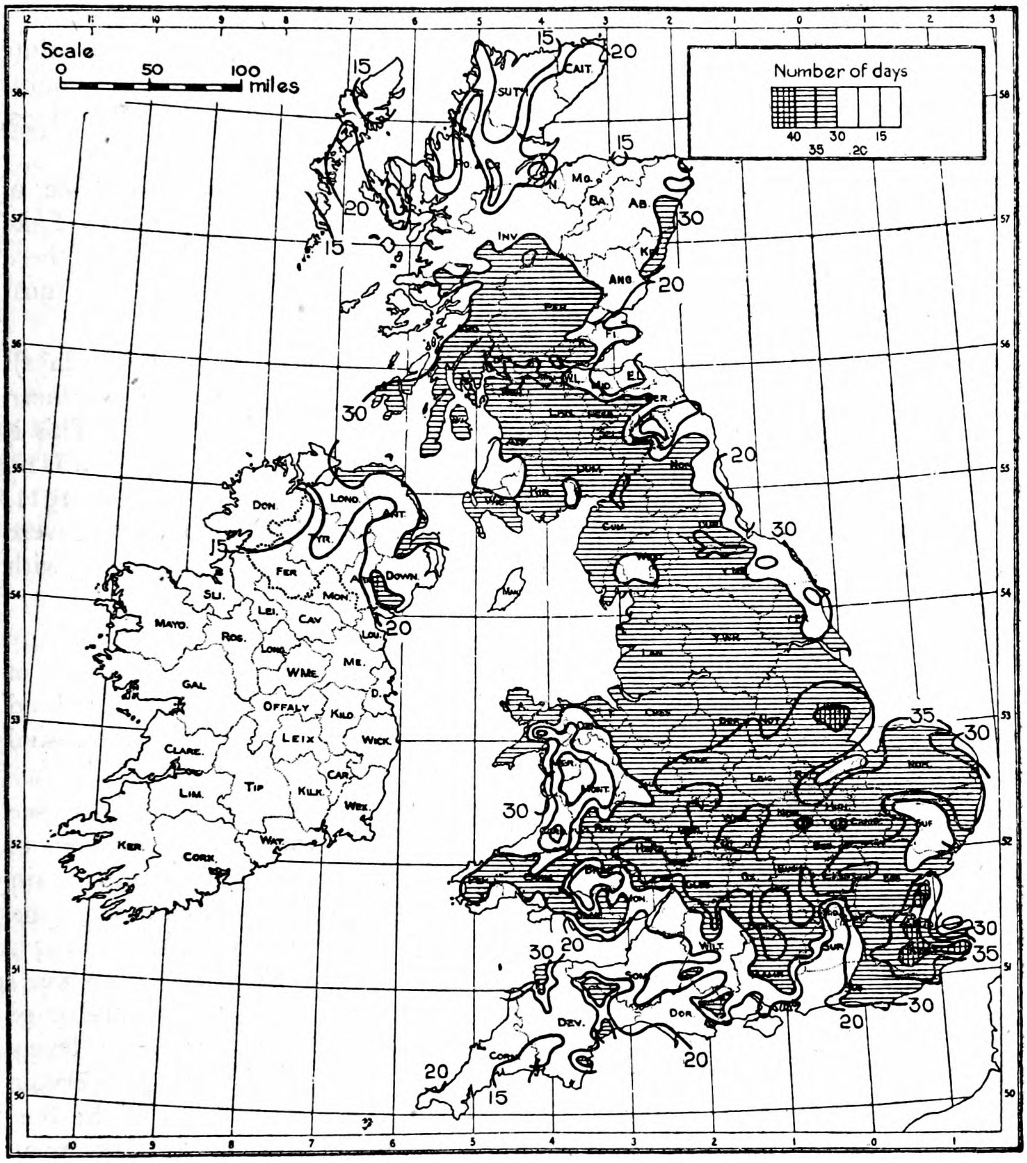

Scale
0
50
100
miles
Number of days
40
30
15
35
20
15
20
15
20
15
30
20
30
20
30
15
20
35
30
30
30
35
30
20
30
20
20
15
Cait.
Sut.
Ma.
Ba.
Ab.
Inv.
Kc.
Ang.
Per.
Fi.
El.
Ber.
Ayr.
Dum.
Kir.
Wig.
Nor.
Cum.
Don.
Lond.
Ant.
Tyr.
Fer.
Down.
Mon.
Arm.
Su.
Lei.
Cav.
Mayo.
Ros.
Lou.
Long.
Me.
W.Me.
Gal.
Offaly
Kild.
D.
Leix
Wick.
Clare.
Car.
Lim.
Tip.
Kilk.
Wex.
Ker.
Cork.
Wat.
Yor.
Lan.
Ches.
Derby.
Nott.
Lin.
Nor.
Leic.
Suf.
Glo.
Wilt.
Som.
Dor.
Dev.
Corn.
Sur.
Ken.

FIG. 1—GREATEST NUMBER OF CONSECUTIVE DAYS WITHOUT MEASURABLE RAIN, JULY 29–SEPTEMBER 16, 1947

Over a large part of the country, this period gave the longest absolute drought on record. This is particularly the case in northern England, as far south as Buxton, and also over much of Scotland, where the longest duration previously recorded had rarely exceeded 25 days and only in isolated coastal districts had reached 30 days.

The longest droughts occurred at—

		days
Wye Agricultural College (Kent)	July 29–September 16	50
Wellingborough (Northamptonshire)	July 29–September 10	44
St. Neots (Huntingdonshire)	July 29–September 10	44
Woodhall Spa (Lincolnshire)	July 29–September 10	44

Only in the famous spring drought of 1893 has so long a period of absolute drought been recorded. Then the longest well authenticated, absolute droughts covered 60 days within the period March 4 and May 14, 1893, at Hastings, Winchelsea, Lewes and Haywards Heath.

A noteworthy feature of the August 1947 drought was the absence of measurable rain in the mountainous districts. Thus in the English Lake District at Borrowdale (the Moraine), Watendlath Farm and Keswick there was no measurable rain from August 3 to September 3 and hikers there must have found their mackintoshes an embarrassment.

The driest period over the country as a whole was August 7–31 (25 days), when the general rainfall over England and Wales, Scotland and Northern Ireland, only amounted to about 0·03, 0·04 and 0·09 in. respectively. This is the driest period over the whole area for which data are available. There was no rain over Northern Ireland during the eleven days August 10–20. In 1911, a year of frequent droughts, the driest periods over England and Wales were July 3–15 (13 days) with 0·013 in., January 26–February 9 (15 days) with 0·034 in. and June 1–11 (11 days) with 0·036 in.

The abnormal conditions justified an examination of all records to see if any days could be found without measurable rain at any station. No records of measurable rain were found at stations in Great Britain and Northern Ireland during the seven days August 13–14 and August 25–29. It is most unusual for any day to have no rain anywhere in the country.

The effects of the drought are illustrated by the two photographs (see photographs facing pp. 260 and 261), kindly made available by the City of Birmingham, Water Department. The first shows the up-stream face of the main Caban Dam, and the second a submerged dam farther up-stream with the Careg Ddu Viaduct. The photographs were taken on November 2, 1947, when the level of the Caban Reservoir was 68 ft. 6½ in. below top water level. The lowest level in 1947 in the Caban Reservoir was reached on November 9, when the level was 70 ft. 4½ in. below top water level. The normal water levels are easily discernable in the photographs. The storage capacity of the reservoir is 7,815 million gallons. The photographs give a good indication of the fine country in which the reservoir is situated, but the Caban Dam appears more impressive from the down-stream side, especially when the reservoir is overflowing, being 122 ft. high from stream bed to crest level and 610 ft. long.

METEOROLOGICAL RESEARCH COMMITTEE

The eleventh meeting of the Physical Sub-Committee of the Meteorological Research Committee was held at the Royal Aircraft Establishment, Farnborough, on June 22, 1950, by kind permission of the Director, R.A.E. Before the meeting members were shown the work of the Meteorological Research Flight.

The exceptional turbulence experienced by the De Havilland Comet aircraft on November 14, 1949, and the associated weather conditions were described in papers by Dr. G. S. Hislop, British European Airways, and Mr. J. K. Bannon, respectively; further investigations of jet-streams, regions liable to high-altitude turbulence, were discussed.

Temperature inhomogeneities in the free air, from a paper by Dr. R. Frith[1], were discussed and a paper on humidity in the upper troposphere and lower stratosphere[2], by Mr. J. K. Bannon, was noted.

A paper on the distance over which an aircraft might expect severe icing in certain weather conditions[3], by Mr. R. F. Jones, was received with interest. Diurnal variations of various weather elements over the ocean were also discussed.

The tenth meeting of the Synoptic and Dynamical Sub-Committee was held on July 19. The problem of the formation of radiation fog was discussed at length, emphasis being placed on the need for a better knowledge of the various physical processes involved and for a realisation of those factors which were important and those which may be neglected. The relevant part of the report on the observations made at various heights at Rye[4] was noted.

A report by Mr. F. H. Bushby[5] on Charney and Eliassen's one-dimensional numerical method for calculating motion of barotropic disturbances in a westerly airstream, was received with interest. The method, though very crude, is an attempt at numerical forecasting; possible improvements and alternative methods of attack were discussed.

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[1] Met. Res. Pap., London, No. 552, 1950

[2] Met. Res. Pap., London, No. 563, 1950

[3] Met. Res. Pap., London, No. 564, 1950

[4] Met. Res. Pap., London, No. 546, 1950

[5] Met. Res. Pap., London, No. 556, 1950

OFFICIAL PUBLICATION

The following publication has recently been issued:—

PROFESSIONAL NOTES

No. 102—*Sandstorms on the northern coasts of Libya and Egypt.* By E. A. Lunson, B.A.

This note discusses the general weather conditions associated with khamsin depressions along the Mediterranean coast of Tripolitania, Libya and Egypt. Part I is a general discussion of these sandstorms—how they arise, how and where they are intensified and what effect they have on flying conditions. This concludes with a tentative classification into " good, moderate and poor " areas of districts between Tunis and the Canal Zone which are affected by these storms. In Part II the development and passage of a typical khamsin depression is traced from Malta to the Suez Canal.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society on June 21, 1950, with the President, Sir Robert Watson-Watt, F.R.S., in the Chair, Mr. H. H. Lamb presented a paper entitled " Types and spells of weather around the year in the British Isles: annual trends, seasonal structure of the year, singularities ".

Mr. Lamb said his work was based mainly on a classification of daily weather maps of the north-east Atlantic, for the fifty years 1898-1947, made by Capt.

Levick, R.E., and presented by him to the Forecasting Research Division. The maps were classified into seven types: anticyclonic (anticyclones over or near the British Isles), cyclonic (depressions over or frequently passing over the British Isles), westerly, north-westerly, northerly, easterly and southerly. Less than 1 per cent. of the maps were unclassified.

From this classification the outstandingly long spells of weather, lasting over 25 days, had been picked out. Mr. Lamb showed frequency curves of the occurrence of these long spells and of the occurrence of each of the seven defined types on every day of the year. Among the many interesting facts revealed by these curves were: long spells of all types are most frequent from the middle of July to the middle of August and from late September to early November and least frequent in early September and from April to June; anticyclonic spells are most frequent in early October; cyclonic spells in July–August and in October; westerly spells in December–January; north-westerly spells in July; northerly spells in April–May; easterly spells in February–March and in October. Westerly spells are decidedly infrequent in May and easterly and southerly ones in the middle of summer. Westerly spells have a higher frequency, over 20 per cent., around the turn of the year than any other type at any season. Southerly spells are infrequent at all times.

Turning to the frequency of types on individual days a brief summary of the findings is: anticyclonic type, most frequent in summer and early autumn and least in late October; westerly type, the most frequent of all types with maximum frequency in early January and late August and minimum in May; north-westerly, little annual variation; northerly, most frequent in April and May and least from early December to early February; easterly, most frequent in late April to early May and late autumn and very markedly infrequent in high summer; southerly, little annual variation but least frequent in summer; cyclonic, most frequent in late July and August and again in October and least in early to mid September.

From these results Mr. Lamb suggested a division of the year into the five periods or natural seasons of:—

High summer, June 18 to September 9.

Autumn, September 12 to November 19.

Forewinter, November 20 to January 19.

Late winter or early spring, January 20 to March 29.

Spring or early summer, March 30 to June 17.

Mr. Lamb then described the short-period recurrences of weather types known as "singularities" revealed in the classification. He described 21 of these. Some of them such as the cold spells of early May, the anticyclonic foggy weather of late November, the "Indian summer" anticyclones of late September, and the late autumn rains of October are well known.

To the forecaster, Mr. Lamb pointed out, the work was of value as a general guide, particularly at times when a long spell is becoming established and is threatened with breakdown. The outlook could on such occasions be judged in the light of the historical trends of the stability of long spells of the particular type at the particular time of the year.

Mr. Gold, speaking in the discussion, considered that a more detailed classification, such as he had given in *Geophysical Memoirs* No. 16, was needed for the use of analogues in forecasting, and that it would be better to give the mid points of spells instead of the less definite beginning and end, and that in the north-easterly type the sunshine over quite a small area in southern England varied considerably. Dr. Crowe, referring to the relation between weather type and rainfall records, said that rainfall regimes cannot be related to the pressure type over such a big area as Great Britain, and also suggested that singularities can vary with the particular 50 years considered.

Dr. Tor Bergeron, Professor of Meteorology at Uppsala University and Symons Medallist, lectured to the Society on the evening of June 28, 1950, on the subject of " Tropical hurricanes ".

Dr. Bergeron referred, in opening his lecture, to the old theories of the formation of these storms, namely Ferrel's convective and Dove's kinetic hypotheses. He said his own interest in them commenced about 1928 when he considered the probable factors for their formation were an unstable atmosphere and a pre-existing low on the intertropical front. This view was supported by the absence of such storms in the tropical South Atlantic and south-east Pacific where the intertropical front was never found.

Now recently Palmén had studied the environment curves of air over the Caribbean Sea and shown that, whereas in September there was convective energy available at all levels to 300 mb., in February, though there was an over-all small positive balance for convection to 300 mb., the convective energy was negative in the lower layers. Dr. Bergeron showed charts of the areas of sea temperatures exceeding 80–81°F. in September and March which outside a 10° belt on the equator and the tropical South Atlantic corresponded well with the charts of areas of formation of tropical storms. The storms cannot form within 5° of the equator because of insufficiently strong Coriolis acceleration.

Dr. Bergeron then linked the formation of tropical storms with recent work done partly by the United States Thunderstorm Project on the structure of cumulonimbus clouds. It had been shown by Riehl and others that the rain of thunderstorms over land produced by evaporation and cooling of the surface a cold low-level " high-pressure " area which effectively prevented a gigantic convective development in Ferrel's manner such as took place in the tropical storm. Over the tropical sea the surface temperatures were much less affected by the rain, but nevertheless every thunderstorm did not develop into a tropical storm, and the explanation was that, as Riehl had shown, a pre-cursory low was necessary. This pre-cursory low provided the necessary convergence in the initial stages to overcome the effect of the tendency to high pressure at the surface.

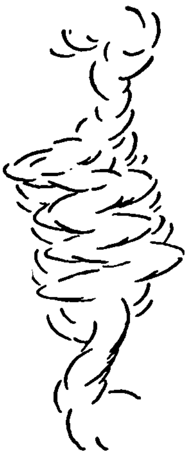
The tropical storm of September 17, 1947, passing over the narrow Florida peninsula from the Atlantic to the Gulf of Mexico, was described to show that the main rainfall was symmetrical in a ring about the centre and outside the area of maximum wind. The down-current produced by the rain assisted the storm circulation in the vertical plane caused primarily by the temperature structure (acceleration due to the isobaric-isosteric solenoids). The storm of October 14–16, 1947, which came inland over South Carolina was also described to show how a tropical storm soon began to die under the influence of the surface " cold high " as it came overland. The central pressure of this storm rose from 975 to 1000 mb. in 30 hr., but the degenerating cloud system was carried on to Chicago.

Dr. Bergeron also gave some illustrations of " tropical storm " formations in temperate zones such as the cyclone of July 9, 1929, over the Baltic.

LETTERS TO THE EDITOR

Cloud phenomenon near Ferring, Sussex, May 14, 1950

At 1600 B.S.T. on May 14, 1950, I noticed from Ferring, near Worthing, Sussex, a small white cloud in an otherwise quite clear sky, which had a definite spiral pattern, as in the sketch below. It remained visible for about twenty minutes, gradually fading and the upper part shearing to the left. It was travelling very slowly from the south. It reminded me somewhat of a small poorly developed Contessa del Vento and was probably due to a local whirl in the free air.



C. E. P. BROOKS

June 1950

[The Larkhill and Downham Market ascents for 1500 G.M.T. on May 14 show that the wind was NE. in the lowest levels steadily backing and becoming NW. at about 300 mb. (30,500 ft.). From 40,000 to 50,000 ft. the wind was westerly. The air was extremely dry at all levels up to the limit of the humidity observations at 350 mb.—Ed. *M.M.*]

Altocumulus castellatus clouds

Mr. R. H. Eldridge, in his letter in the June number of the *Meteorological Magazine*, raises a difficult and important point in cloud classification. He is undoubtedly right in his main point, namely that the tops of typical altocumulus castellatus clouds consist of small turrets, nearly always in a group or along a belt, with each turret formed originally from an ordinary altocumulus cell. The parent layer has frequently a fairly normal appearance for an appreciable time, but the cells grow thicker and then erupt upwards, sometimes quite suddenly, as is well shown on one of the German cloud films. If the small cells amalgamate into large agglomerations with domed tops they should be called cumulus congestus. Frequently they soon become cumulonimbus, and this had already happened in the case of the cloud depicted in the photograph in the issue of December 1949, since fibrous structure is visible. The freezing level was at 12,500 ft., so that the top of the cloud almost certainly exceeded 20,000 ft. It was much farther away than the cloud in the foreground with a base at about 8,000–10,000 ft. It is interesting to note that this foreground cloud shows no turrets, but nevertheless there is no reason to doubt that it was the parent layer of the cumulonimbus. This cannot be deduced with complete certainty from the photograph, but the observed atmospheric structure on that day supplies strong additional evidence for it. Thunder and lightning could have accompanied this cumulonimbus column. There are many cases on record of thunderstorms in the British Isles with the main cloud base at 10,000 ft. if not higher. The one on August 24, 1944, gave over an inch of rain over quite a large area (see *Meteorological Magazine* for November 1949, p. 309). In a dry climate, like that of the Mediterranean in summer, high-based thunderstorms are of course more frequent, and the base probably sometimes exceeds 15,000 ft.

A similar type of cloud with a sharply defined edge should always be called cumulus congestus. The current edition of the " International Cloud Atlas " was published as far back as 1932. It remains a very valuable publication, but it does not give adequate guidance on the point under discussion. Its Plate 55 shows an example of what is called stratocumulus castellatus, and this certainly exists in the foreground of the picture, but the dominant clouds are large cumulus, and the illustration is therefore misleading, and more especially the caption under the photograph. The picture itself is of exceptional interest. The nearest clouds in that photograph illustrate the true castellatus form, but in the larger clouds farther away the small turrets have amalgamated into larger agglomerations. In such cases the cell structure at the cloud base often remains much as before, apart from a general darkening. Many examples of altocumulus opacus and some of stratocumulus opacus have cumulus tops which are invisible from the ground. An observer can only report what he sees, but it is worth while to keep a good look-out for the castellatus form and for the tops of large cumulus or cumulonimbus in such conditions, if there are any gaps in the cloud sheet.

A new edition of the " International Cloud Atlas " is in course of preparation, and a committee formed by the International Meteorological Organization for this purpose has already had two meetings at Paris. All the difficult problems have had a very full discussion, and every effort is being made to give clear and definite guidance to observers. It is in a few cases necessary to lay down rather arbitrary distinctions which have the nature of conventions framed with the object of securing the maximum attainable uniformity among observers. Complete standardization is impossible, since nature shows infinite gradations in the structure and appearance of clouds, and also a very large number of transformations, so that marginal categories are unavoidable, but at least the situation will be improved.

C. K. M. DOUGLAS

July 5, 1950

NOTES AND NEWS

Whirlwind near Walsrode, Germany

At 1800 G.M.T. on April 26, 1950, a depression of central pressure 993 mb., was centred over Holland. A cold front which extended to the Frisian Islands. thence south-eastwards, was moving in a north-easterly direction at about 30 kt. over north-west Germany and there was a marked trough of low pressure along the front. In the Buckeburg-Bad Eilsen area, the frontal passage was associated with gusts reaching 55–60 kt., a rise of pressure of 2–3 mb. and a fall of temperature from 52°F. to 36°F. The freezing level over Hanover fell from 4,500 ft.

to 2,000–2,500 ft. during the time between successive upper air ascents made at 1400 and 2000.

A report on " Unusual Weather " on April 26 was received from a British Army unit in the Walsrode area (52°50′N. 09°30′E.). This report reads as follows:—

". . . At approx. 1825 hours a gust of wind of great force suddenly sprang up and blew for about 30 seconds bending trees right over. This was followed by a dead calm for approx. 1 minute during which time the sky grew dark. The wind blew up again rather like a whirlwind. It confined itself to an area of approx. 200 sq. yards and lasted for approx. 45 seconds. The strength of the wind was such that it sounded like the shrill whine of a missile travelling at high speed and the noise was heard 8 kilometres away.

The ' whirlwind ' effect moved within the 200 sq. yards during which time it uprooted four very large trees, half uplifted several others, lifted the roof off a shed, blew windows in, took off the tiles and large areas of roofing from several buildings. A fire bell weighing ½ cwt., suspended by an iron chain from the branch of a large tree, and which appeared to be caught by the ' fringe ' of the whirlwind, was blown into a horizontal position for quite a number of seconds.

The duration of the whole incident was approx. 2½ minutes, after which time the weather returned to normal."

It has since been ascertained from the army unit that the phenomenon which appeared to form over the area was not accompanied by any heavy rain or hail. Observers were not clear as to whether a funnel extended downwards from the base of the cloud but they were well aware of a definite whirlwind circulation which sucked up such a considerable amount of dust and debris that the adjacent fire piquet thought it was a column of smoke and reported a possible fire.

REVIEWS

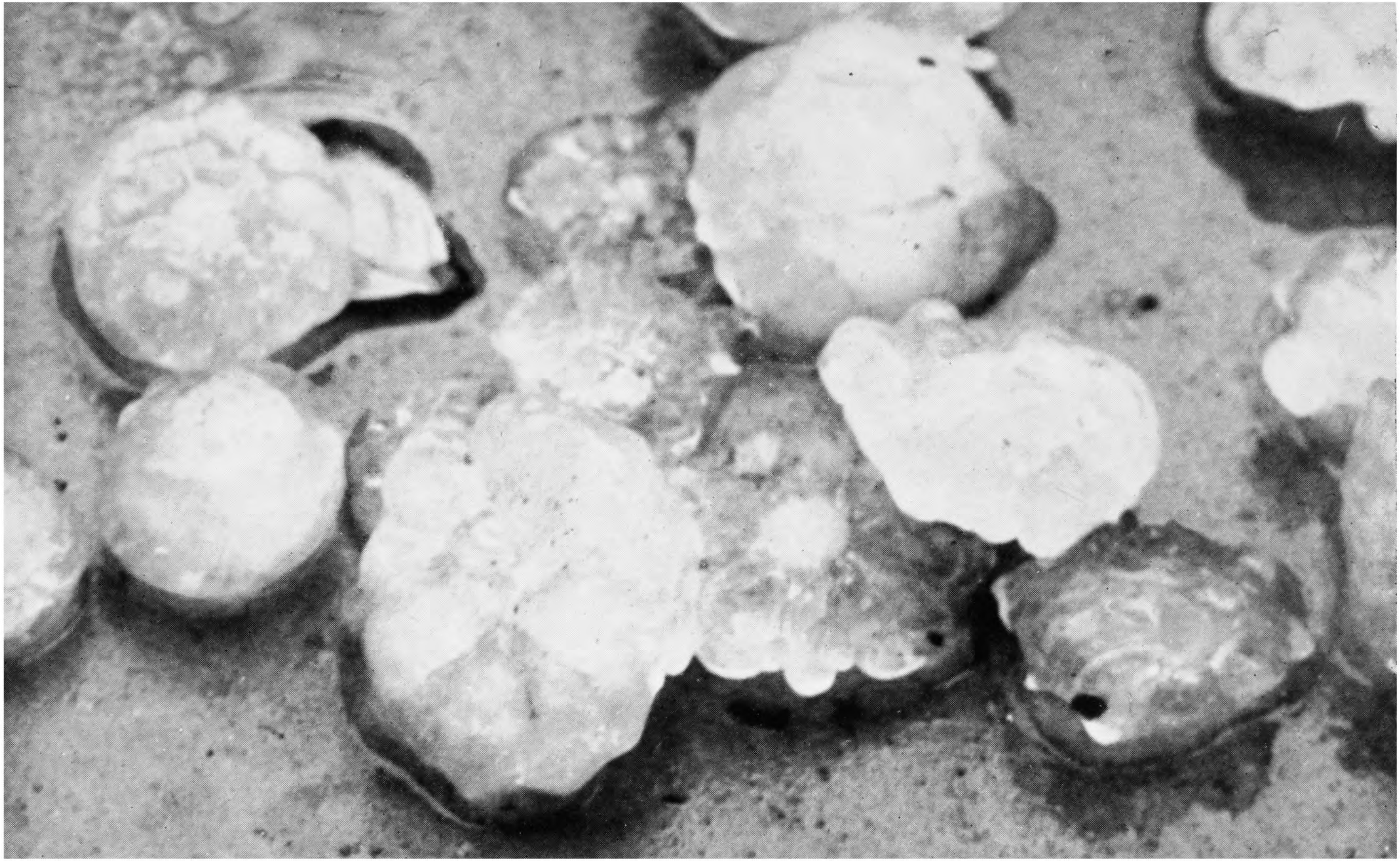
The Thunderstorm—Report of the Thunderstorm Project. United States Weather Bureau. 10 in.×7½ in., pp. ix.+287, *Illus.* Washington D.C. 1949. $2.25.

The United States Thunderstorm Project was probably the most elaborate single meteorological investigation ever made.

The United States Government agencies concerned—Air Force, Navy, National Advisory Committee for Aeronautics, and Weather Bureau—did not keep the results to themselves until a comprehensive report could be prepared, but published for the information of all the world valuable reports and papers during the progress of the investigation. Now we have the eagerly awaited report on the whole Project. The opening paragraph of the preface describes the Report in the following words: " This publication is to be considered as the final report of the present phase of the Thunderstorm Project. All the research possibilities suggested by the data obtained on the Project have not been explored. Only the more obvious results are presented herewith, but it is expected that some of the participants in the analysis and other meteorologists will use the abundant material to glean additional knowledge of thunderstorms."

The Report opens with an introduction of 13 pages which gives the history of the Project, the plan of observations, description of the areas of operations and

[*To face p.* 268



Reproduced by courtesy of F. Greenaway

HAILSTONES AT NORTH CRAWLEY, NEAR NEWPORT PAGNELL, BUCKS
(Actual size)
(see p. 247)

To face p. 269]

Reproduced by courtesy of D. Wigmore

THREE-LEGGED RACE AT THE HARROW METEOROLOGICAL OFFICE SPORTS MEETING,
JULY 26, 1950

a statement of the number of storms investigated, number of aircraft flights into storms and so forth. The main Report, occupying 237 pages consists of three parts, entitled description of the thunderstorm, flight operations in thunderstorm conditions and examples. Part 1 is divided into eight chapters dealing with thunderstorm structure and circulation, turbulence and hydrometeors within the thunderstorm, thunderstorm weather near the surface, electric fields inside the thunderstorm, the thunderstorm as disclosed by radar, effect of environment wind field on existing thunderstorms, preferred areas of thunderstorm development, and squall lines. The main reason for the Project was the necessity for accurate information on flight in thunderstorms. This information is provided in Part 2, " Flight operations in thunderstorm conditions ". To many meteorologists, Part 3, which contains very detailed reports and observational data on five thunderstorms, will probably prove the most interesting part of the book in providing material for study. Finally, there are a bibliography, five appendices describing the instruments, and an index.

The Project used two areas, one near Orlando, Florida, where thunderstorms are nearly all of the air-mass type, and another in Ohio where frontal storms occur as well. The surface stations were equipped with autographic instruments; there were 55 such stations spaced about one mile apart in Florida and the same number spaced about two miles apart in Ohio. Upper air temperatures and humidities were measured by both radio-sondes and aircraft, and upper winds by the radar-wind method and by radio direction-finding on the radio-sondes. Aircraft flights were made to measure vertical motions, horizontal and vertical temperature distribution and the electric field; generally five aircraft spaced at intervals up to 25,000 ft. flew through storms. A vast amount of information on thunderstorm structure is now available from this dense network of stations and observations by specially trained aviators and specially fitted aircraft.

The general picture of the development of air-mass storms which emerges is briefly as follows: the predominant feature of the cumulus stage of development is the up-draught. No radar echo appears until the top of the cloud reaches above the freezing level. The rising column of air is shown to entrain air as it ascends and the mixing of the rising air with the air of the environment is of great importance. Rain first appears several thousand feet above the freezing level and higher up there is a gradual transition to dry snow. During this development stage the thunderstorm cell which is initially about two miles wide grows to a width of about six miles. The fall of rain at the surface marks the transition from the cumulus to the cumulonimbus, and from then onwards the region originally occupied by an up-draught contains a down-draught produced by the rain. The up-draught is found in a region adjacent to the down-draught and in the mature storm may have a speed in places of 100 ft./sec. The down-draught spreads out in the lowest layers of the atmosphere and is cooled by the evaporating rain. This spreading out of the cool down-draught air cuts off the supply of warm air to the up-draught so that the storm dissipates. It may, however, in turn stimulate the ascent of adjacent masses of warm air and so lead to the formation of more thunderstorms.

The description is substantiated in detail by charts of convergence and divergence and short-period rainfall measurements. Tables and figures give the frequency distributions of the velocities and widths of the up and down currents.

For specifying the intensity of the turbulence in the storm as found from accelerometer recordings made on the aircraft, use is made of the "effective gust velocity" concept which represents the speed of a "sharp-edged gust" that would give the same acceleration as that actually experienced. The maximum effective gust velocities encountered were of the order of 40 ft. per sec. but only a small proportion exceeded 20 ft. per sec. The most frequent horizontal distance over which the changing wind speed giving the gust occurred was 150 ft.

Heavy icing was encountered infrequently and on no occasion made safe flight impossible by the P-61C aircraft employed but this lack of serious icing is ascribed to the aircraft not being sufficiently long in the cloud.

Although the initial stimulus to the Project was the promotion of the safety of flight this matter, important though it is, does not dominate the Report, and no one can say that the purely scientific side has been neglected. Thus detailed measurements were made of the electric field and these are correlated with the up and down currents. Further, the pressure variations at the surface are studied in detail.

This Report must now be considered the prime source of information on thunderstorm structure. Bound in buckram and printed on art paper it is produced in a manner worthy of the work described. G. A. BULL

On the formation of drops in clouds and fog. By R. R. Vierhout. Koninklijk Nederlandsch Meteorologisch Instituut No. 102. Mededeelingen en Verhandelingen Serie B, **2**, No. 12. 12¼ in. × 8¾ in., pp. 20. 's. Gravenhage, 1948. 2·50 florins.

The author first discusses the rate of evaporation of an isolated drop on the basis of the rate of diffusion of water-vapour molecules in air and the kinetic theory of gases and following Fuchs in the general treatment. The effect of neighbouring drops on this evaporation rate is next examined and the time computed for complete evaporation of drops of various sizes in a cloud with dimensions of the order of a few hundred metres and one hundred per cent. relative humidity. The results indicate that a drop of radius 10 microns has a life of about 45 minutes, but that if the order of magnitude of the drop radius is decreased or increased the life of the drop is measured in seconds or days respectively. Somewhat similar results are obtained for the time of growth of a drop in a supersaturation of a few tenths per cent. The author next considers growth of drops by coalescence, resulting from larger drops overtaking smaller drops while falling under the influence of gravity, and obtain, numerical results indicating that a cloud thickness of about 1,300 m. is necessary for drops to grow to a radius of 1 mm. by coalescence. Finally the author considers the forces between two drops due to condensation and evaporation, and shows that these forces are very much greater than the electric forces between two singly charged ions unless the drop radius is a fraction of a micron.

It is odd that in a memoir with this title the influence of the nucleus of condensation in lowering the vapour pressure over the drop receives only a cursory mention and is not taken into account in the computations. It is surprising also to find Stokes' law assumed to hold for the terminal velocity of drops with radius up to 1 mm. Assumptions such as these may not invalidate the general character of the results but must seriously affect the actual numerical values obtained. In short, the physical basis of the work has received less attention than the mathematical superstructure. It seems desirable also to register a protest against the use of the word " drizzle " to describe drops having a diameter of 2 mm.

The memoir is unnecessarily difficult to read as a result of the almost complete absence of sectional headings.

A. C. BEST

Meteorology for Seamen. By Cdr. C. R. Burgess, O.B.E., R.N. 8½ in. × 5½ in. pp. xi+252. *Illus.* Brown, Son and Ferguson, Ltd., Glasgow. 1950. 15*s*.

The seaman will find plenty of useful information in this concise and attractive book on marine meteorology. It is divided into four parts: I—" Factors which go to make up the Weather ", II—" The Climate of the Oceans ", III—" Weather Forecasting ", IV—" Observing and Recording the Weather ". There are plenty of good clear diagrams, many excellent and unusual photographs, as well as some clearly drawn examples of weather charts.

The book is evidently not intended for cramming for examinations; no attempt is made to " blind the reader with science ", but it is suitable for general reading on the subject, without expert knowledge. The author might easily have given it the sub-title "A practical meteorological guide for seamen", for this is what it is.

Written by a seaman for seamen it is full of helpful hints, which are not always found in books on this subject, and which may well be of value to the seaman who cares to apply weather knowledge for the safety or economical operation of his ship. This particularly applies to the chapter on " Fog, Mist and Haze " (probably the mariner's greatest enemy), and that on " Weather Forecasting by Seamen ". For example, in the former chapter it is pointed out how and why visibility improves down-wind in Arctic sea-smoke, and up-wind, *i.e.* towards warmer water, in the case of sea fog; also that early morning is sometimes unsuitable for making a landfall when there is a liability of radiation fog. The paragraphs on forecasting sea fog, by the use of the wet- and dry-bulb and sea temperature observations, are interesting, and should prove helpful in waters where this is likely to occur; as is also the suggestion that foggy areas can be avoided, in some cases, with the help of isotherm charts in conjunction with the above readings. Chapters 20 and 21 give guidance to the mariner on the subject of forecasting his weather by using the information contained in weather bulletins for shipping. The use of baratics and synoptic information in drawing up a weather chart in the simplest and most time-saving manner, so as to give a more localised picture of the weather than that which can be given in ocean forecasts, is discussed in detail. If this guidance is followed, a shipmaster might, in certain cases, be able to use weather information to his advantage, by avoiding areas of unfavourable weather; thus by an alteration of course and/or speed a better passage might be made, with less liability of damage. Chapter 21, " Watch your own Weather ", points out that one should not rely implicitly on official forecasts when out in the middle of an ocean, but should always be on the look out for " on the spot " changes of pressure, wind and weather. Portents of the sky and sea, used by seamen throughout the centuries, are interestingly discussed in the light of modern knowledge.

The formation, movements and meetings of the various types of air masses, and the subsequent effects thereof, are dealt with in a straightforward manner.

The remarks on general phenomena are illuminating and call the attention of the reader to wonders of nature, which will give added interest to any voyage.

Notes on " Radar and Weather " deal not only with various meteorological effects upon the performance of this aid to navigation, but also the meteorological uses to which radar can be put.

There are a few points which merit criticism; on p. 62 in the paragraph dealing with the position and shape of the new moon, it is stated: " only in autumn does it lie with its horns pointing downwards in middle latitudes "; this aspect can never be seen after sunset in any latitude, and can only be seen in daylight when the sun's altitude is greater than that of the moon's. In Chapter 15, dealing with tropical revolving storms, no mention is made of the necessity of stopping the ship in order to ascertain whether the wind is backing or veering, in relation to the storm area passing over the ship at that place. In Chapter 20, " Weather Forecasting by Seamen ", the statement on p. 148 that it takes two hours to plot a weather map for the eastern North Atlantic may perhaps frighten some mariners, but the author seems to be referring to a full synoptic chart, and not to the Atlantic Weather Bulletin which can, with practice, be plotted in about an hour.

These items, however, do not detract from the value of this book. To have written on such a large and complex subject as modern marine meteorology, to have kept it within a reasonable size and price, and yet to have touched on all that the mariner needs, is no mean achievement. This book will be a useful addition to a ship's officers' library.

R. REID

OBITUARY

Arthur Charles Marsh.—We regret to record the death on April 22, 1950, of Mr. Arthur Marsh of 113, Poole Road, Bournemouth, a Fellow of the Royal Meteorological Society since 1920 and Meteorologist to the Bournemouth Corporation since 1937. When Mr. Marsh returned from the first world war, he became deputy to his father-in-law Charles Dales (Bournemouth's first official Observer who was appointed in 1920). As Mr. Dales advanced in years they reversed their roles, and from 1937 onwards Mr. Marsh was the Observer while Mr. Dales served as Deputy until his death at the age of 93 in 1945.

We note with pleasure that Mr. Dennis Bernard Marsh has been appointed as Meteorological Registrar in succession to his father so that the long and useful records from Bournemouth have great prospect of being well maintained.

P. R. ZEALLEY

We regret to report the death of Mr. H. N. Warren, Director of the Australian Commonwealth Meteorological Service, which occurred at Adelaide on August 5, 1950.

METEOROLOGICAL OFFICE NEWS

Bird watching from an ocean weather ship.—During the summer months three ornithologists, members of the British Trust for Ornithology, are sailing aboard the ocean weather ships, for one voyage each, to make observations of the movements of sea birds and study bird migration.

Air Day in B.A.F.O.—Several thousand spectators, mostly Belgian, British, Danish and Norwegian troops, visited the meteorological stand in the exhibition prepared for B.A.F.O. Air Day, held at Gütersloh airfield on June 20, 1950.

The making and collection of observations, and the preparation and analysis of weather charts were demonstrated, and the diverse uses of weather forecasts illustrated. The meteorological instruments exhibited included a sectioned working model of a radio-sonde, a radio-sonde balloon prepared for release, and a facsimile machine reproducing simple synoptic charts.

Marine exhibition.—At the close of the " Science of Weather " exhibition at the Science Museum, South Kensington, mentioned in the June number, the exhibits prepared by the Marine Branch were transferred to H.M.S. *Wellington*, Headquarters Ship of the Honourable Company of Master Mariners, lying off the Embankment, London, for show to the Company's members during the month of July.

High pilot balloon ascent.—A 90-in. pilot balloon with a free lift adjusted to give a rate of ascent of 500 ft./min. was followed for 2 hr. 10 min. at Ronaldsway on May 13, 1950. If the rate of ascent of 500 ft./min. were realised throughout the flight of the balloon, the height reached would be 65,000 ft. On the same assumption the distance from theodolite to balloon when last seen was approximately 60 mi.

Academic success.—The University of Durham has conferred the degree of Doctor of Science upon Mr. F. Pasquill. We offer him our congratulations.

Amateur radio transmissions.—Staff interested in amateur radio are invited to look for station VS9AA operated on the 7, 14 and 28 Mc. Amateur Bands by Mr. S. G. Abbott (Experimental Officer) in the Meteorological Office, Royal Air Force, Khormaksar, Aden. Reports on the quality of reception will be welcomed by Mr. Abbott.

Sports and Athletics

Harrow.—The first annual athletics meeting of the Harrow Meteorological Office Social and Sports Club was held at Alperton Recreation Ground on July 26, and proved an outstanding success. A feature of the meeting was the inauguration of Meteorological Office championship events. The winners of the championship events were D. J. Mannion, Hendon (100 yards), W. Lawson, Leeming (half mile), Miss M. K. Hunt, London Airport (ladies' 100 yards), Central Forecasting Office (mens' relay) and Harrow Office (ladies' relay). The meeting ended very happily with the presentation of medals and certificates by Mrs. J. M. Stagg.

London Airport.—The meteorological office staff at London Airport had a successful day at the first Annual International Sports at the Airport on July 15, 1950. The team of nine gained 10 cups and 4 plaques besides other awards and succeeded also in winning the Bristol Challenge Cup. This handsome trophy was presented by the Bristol Aeroplane Company as a token of their appreciation of services rendered, when the Brabazon visited the airport in June, to be awarded annually to the Operating Company or Airport Department scoring the highest aggregate points during the meeting. The meteorological office scored 89 points, the runners up being H.M. Customs (Landing) with 77 points.

We would offer congratulations to:—

Miss B. Edwards, on winning the Air Ministry Ladies' Tennis Singles Championship for 1950.

Miss N. Edwards and Mr. P. J. Meade on reaching the semi-finals of the mixed doubles of the Air Ministry Tennis Tournament.

Mr. H. G. Stannard on winning the Kingston Prize of the Surrey Rifle Club, with 32 points out of 35.

Corporal E. W. Heasman on winning the mile event at the athletics meeting between Air Ministry Harriers and the Board of Trade held on June 19, 1950.

L.A.C. T. D. Abbott on being selected to compete in the International Services Swimming trials at Aldershot on July 13, 1950.

Horticultural Show.—We would offer congratulations to Mr. B. G. Brame on the award to him of the Banksian Medal for his exhibits at the annual show of the Air Ministry and Ministry of Civil Aviation Horticultural Society held on July 11, 1950. The Banksian is a memorial medal presented by the Royal Horticultural Society to each Society for the competitor gaining most prizes at its annual show.

WEATHER OF JULY 1950

Mean pressure was above 1020 mb. from around the Azores westwards nearly to Bermuda, and above 1015 mb. in the northern half of Greenland and for a considerable distance over the sea to the eastward; in the latter region it was 5–8 mb. above the July normal. The mean was below 1005 mb. immediately to the south of Iceland, being 5–10 mb. below the July normal in that region, which formed part of a much larger area throughout which pressure was below normal, but by a smaller amount. This area extended southwards and south-westwards at least to latitude 30°N. and south-eastwards to include central, southern and western Europe, most of the Mediterranean and the extreme north of Africa. In North America pressure was generally within 1 or 2 mb. of normal.

In the British Isles the weather was mainly unsettled; it was very wet over much of the southern half of England and Wales, in Northern Ireland and west and central Scotland. Sunshine considerably exceeded the average in Scotland, particularly in the north, but totals were less than the average in Northern Ireland and locally in England.

A small anticyclone gave mainly fair weather in the opening days but a trough of low pressure over France caused thunderstorms in south-east England during the night of the 2nd–3rd. On the 3rd a depression over Brittany moved to north-west Germany and further rain, heavy locally, occurred in southern and eastern districts of England. On the 5th another disturbance moved from north-west France to northern Germany and, on the 6th, a shallow depression off the south of Ireland moved to the southern North Sea; rain and local thunderstorms occurred chiefly in southern England and Ireland (2·32 in. at Lansdown, near Bath, on the 6th). The period 3rd to 6th was dull in England and Wales but sunny in the north of Scotland.

From the 7th to 9th a depression was situated on the Atlantic westward of the British Isles; on the 7th and 8th troughs associated with this system caused rain in Scotland and Ireland. On the 9th a shallow trough moved across England; heavy rain and local thunderstorms occurred in the south-east and east in the evening and during the following night (2·14 in. at Odsey, south-west

Cambridgeshire). Temperature rose considerably and the 9th was the warmest day of the month at most places in England; maxima of 80°F. or above were registered at a number of places in the eastern half of the country and temperature reached 85°F. at Mildenhall, near Newmarket. On the 10th and 11th a secondary depression moved east-north-east across Ireland and northern England causing further rain. On the following day a ridge of high pressure, moving east, was associated with fair weather in eastern districts though rain occurred in the west and north. Unsettled weather was renewed on the 13th, when a depression off the west of Ireland moved irregularly north-east and later turned north; rain fell generally on the 13th and, in the west and north, also on the 14th (3·97 in. at Loch Sloy Dam near Loch Lomond on the 13th). From the 15th to 18th a deep depression westward of Ireland moved slowly north-east and brought rain generally on the 15th and showers and local thunderstorms on the 16th and 17th. Rainfall was heavy locally during this spell; for example, 2·08 in. at Llyn Fawr, Glamorganshire, and 2·07 in. at Treherbert, Glamorganshire, on the 16th, 2·23 in. at Onich, Inverness-shire, and 2·10 in. at Fort William on the 17th and 2·26 in. at Blaenau Festiniog, Merioneth, on the 18th. By the 19th an anticyclone over France had intensified, while a trough off south-west Ireland moved north-east. Temperature rose temporarily and fair weather occurred over most of England but rain fell in the west and north; temperature reached 79°F. at Felixstowe and 77°F. at Gorleston and London Airport. A further period of unsettled weather ensued; from the 21st to 23rd an Atlantic depression westward of Scotland moved slowly north. Associated troughs moving slowly east caused showers and local thunderstorms on the 21st, and a secondary depression moved east-north-east across Ireland and northern England to the north of Denmark on the 22nd and 23rd and was associated with more rain and local thunderstorms (2·14 in. at Sheepstor, south Devon, on the 22nd). Thereafter, small wave depressions to the south of England moved east; some rain occurred in the south of England and there were scattered showers in Scotland and Ireland.

Subsequently, an anticyclone off our south-west coasts moved east-north-east to Germany, while a depression off south-east Iceland moved west-south-west. Fair weather prevailed in England from the 26th to 29th, apart from local thunderstorms on the 28th. Troughs of low pressure caused showers in Scotland and Ireland and local thunderstorms occurred in Scotland on the 26th and 27th. On the 30th a trough of low pressure to a depression south of Iceland, moving east, caused some rain in all districts.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales	86	39	+0·4	139	+2	100
Scotland	74	32	+0·6	133	+4	113
Northern Ireland..	71	42	+0·1	191	+7	92

RAINFALL OF JULY 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ..	3·16	133	*Glam.*	Cardiff, Penylan ..	5·17	168
Kent	Folkestone, Cherry Gdn.	2·98	142	*Pemb.*	St. Ann's Head ..	2·64	102
,,	Edenbridge, Falconhurst	2·74	119	*Card.*	Aberystwyth	4·30	141
Sussex	Compton, Compton Ho.	4·22	149	*Radnor*	Tyrmynydd	4·68	114
,,	Worthing, Beach Ho.Pk.	2·75	135	*Mont.*	Lake Vyrnwy	6·22	175
Hants	Ventnor, Roy. Nat. Hos.	4·36	216	*Mer.*	Blaenau Festiniog ..	9·08	107
,,	Bournemouth	4·29	201	*Carn.*	Llandudno	1·48	66
,,	Sherborne St. John ..	4·83	217	*Angl.*	Llanerchymedd ..	2·38	83
Herts.	Royston, Therfield Rec.	5·68	225	*I. Man.*	Douglas, Borough Cem.	3·05	100
Bucks.	Slough, Upton	4·12	215	*Wigtown*	Port William, Monreith	3·06	109
Oxford	Oxford, Radcliffe ..	5·33	225	*Dumf.*	Dumfries, Crichton R.I.	4·30	131
N'hant.	Wellingboro', Swanspool	3·30	144	,,	Eskdalemuir Obsy. ..	6·01	147
Essex	Shoeburyness	2·09	114	*Roxb.*	Kelso, Floors	2·39	91
,,	Dovercourt	2·46	123	*Peebles*	Stobo Castle	3·73	129
Suffolk	Lowestoft Sec. School ..	2·55	112	*Berwick*	Marchmont House ..	2·71	89
,,	Bury St. Ed., Westley H.	2·89	116	*E. Loth.*	North Berwick Res. ..	2·76	107
Norfolk	Sandringham Ho. Gdns.	3·63	142	*Midl'n.*	Edinburgh, Blackf'd. H.	3·11	110
Wilts.	Bishops Cannings ..	5·41	217	*Lanark*	Hamilton W. W., T'nhill	4·37	152
Dorset	Creech Grange.. ..	6·82	278	*Ayr*	Colmonell, Knockdolian	3·43	109
,,	Beaminster, East St. ..	5·22	201	,,	Glen Afton, Ayr San ..	5·38	128
Devon	Teignmouth, Den Gdns.	4·07	175	*Bute*	Rothesay, Ardencraig	6·40	162
,,	Cullompton	5·49	204	*Argyll*	L. Sunart, Glenborrodale		
,,	Ilfracombe	3·36	132	,,	Poltalloch		
,,	Okehampton, Uplands	5·40	167	,,	Inveraray Castle ..	8·63	173
Cornwall	Bude, School House ..	2·93	120	,,	Islay, Eallabus ..	6·75	198
,,	Penzance, Morrab Gdns.	3·88	143	,,	Tiree	6·91	191
,,	St. Austell	4·43	132	*Kinross*	Loch Leven Sluice ..	4·82	167
,,	Scilly, Tresco Abbey ..	3·36	151	*Fife*	Leuchars Airfield ..	3·37	130
Glos.	Cirencester	3·75	145	*Perth*	Loch Dhu	10·12	210
Salop.	Church Stretton ..	3·08	117	,,	Crieff, Strathearn Hyd.	4·95	167
,,	Cheswardine Hall ..	2·66	98	,,	Pitlochry, Fincastle ..	4·74	176
Worcs.	Malvern, Free Library	3·16	139	*Angus*	Montrose, Sunnyside ..	3·83	146
Warwick	Birmingham, Edgbaston	2·95	127	*Aberd.*	Braemar	4·26	166
Leics.	Thornton Reservoir ..	2·26	91	,,	Dyce, Craibstone ..	4·43	146
Lincs.	Boston, Skirbeck ..	2·66	121	,,	Fyvie Castle	3·94	121
,,	Skegness, Marine Gdns.	3·69	169	*Moray*	Gordon Castle	2·79	87
Notts.	Mansfield, Carr Bank ..	1·76	67	*Nairn*	Nairn, Achareidh ..	2·17	85
Derby	Buxton, Terrace Slopes	3·45	88	*Inverness*	Loch Ness, Garthbeg ..	2·91	120
Ches.	Bidston Observatory ..	1·94	75	,,	Glenquoich	7·40	115
Lancs.	Manchester, Whit. Park	3·14	95	,,	Fort William, Teviot ..	7·96	163
,,	Stonyhurst College ..	4·38	113	,,	Skye, Duntuilm ..	3·74	100
,,	Squires Gate	2·74	99	*R. & C.*	Tain, Tarlogie House ..	3·47	127
Yorks.	Wakefield, Clarence Pk.	1·64	65	,,	Inverbroom, Glackour..	2·78	75
,,	Hull, Pearson Park ..	2·99	128	,,	Applecross Gardens ..	5·06	127
,,	Felixkirk, Mt. St. John	3·38	124	,,	Achnashellach	5·13	105
,,	York Museum	1·91	76	,,	Stornoway Airfield ..	3·13	109
,,	Scarborough	2·58	106	*Suth.*	Loch More, Achfary ..	5·32	99
,,	Middlesbrough.. ..	2·87	112	*Caith.*	Wick Airfield	3·56	135
,,	Baldersdale, Hury Res.	3·20	100	*Shetland*	Lerwick Observatory ..	3·49	152
Norl'd.	Newcastle, Leazes Pk. ..	3·28	128	*Ferm.*	Crom Castle	5·50	158
,,	Bellingham, High Green	3·82	116	*Armagh*	Armagh Observatory ..	4·75	164
,,	Lilburn Tower Gdns. ..	2·38	96	*Down*	Seaforde	6·23	195
Cumb.	Geltsdale	3·70	107	*Antrim*	Aldergrove Airfield ..	6·09	217
,,	Keswick, High Hill ..	3·41	89	,,	Ballymena, Harryville..	8·93	260
,,	Ravenglass, The Grove	4·38	117	*L'derry*	Garvagh, Moneydig ..	6·21	192
Mon.	Abergavenny, Larchfield	5·03	202	,,	Londonderry, Creggan	6·55	179
Glam.	Ystalyfera, Wern House	7·48	163	*Tyrone*	Omagh, Edenfel ..	5·62	165

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"SFERICS" AND THE LIGHTNING DISCHARGE

By R. H. GOLDE, Ph.D.

In a Friday evening discourse before the Royal Institution on May 18, 1860, Sir William Thompson,[1*] as he then was, expressed the conviction that "electric indications" such as those obtained with a water-dropping collector connected to an electrometer "will be found important additions to our means for prognosticating the weather". In fact, from a pronounced movement of the electrometer during the discourse the lecturer predicted that the preceding dull rainy weather would give way to fairer conditions, an observation which was strikingly confirmed by the cessation of the rain and the onset of fair weather conditions which lasted for several days after!

Unfortunately Lord Kelvin's hope "to see the atmospheric electrometer generally adopted as a useful and convenient weather-glass" was not fulfilled. However, in his quest for improved weather forecasting the meteorologist has been able to make good use, in fact the only practical use so far, of another electrical manifestation, namely the lightning discharge. In an article[2] which appeared in this Magazine the "sferics" organization of the Meteorological Office has been described, and it has been stated that the atmospheric disturbances on which this service is based are caused by lightning discharges at distances of hundreds or thousands of miles from the point of recording.

The present article discusses those characteristics of the lightning discharge which may assist in an understanding of the development of atmospherics.

Initiation of the lightning discharge.—Our knowledge of the thermodynamical processes underlying the development of cumulus clouds has been greatly extended by a recent comprehensive investigation carried out by the United States Air Force and reported by Byers[3]. From these investigations a cumulonimbus cloud is now known to consist of a number of individual cells each of which has a regular life cycle with its corresponding state of electrification.

In the present context it is of special interest to find that the lower region of an active cell contains water drops while the upper part is filled with ice crystals, the whole cell being subject to violent winds both upwards and downwards. This picture of a thundercloud confirms Simpson's[4] earlier conception, derived from balloon measurements, which led to the picture of a typical thundercloud reproduced in Fig. 1. This shows a bipolar charge distribution with an upper positive charge and a lower negative charge,

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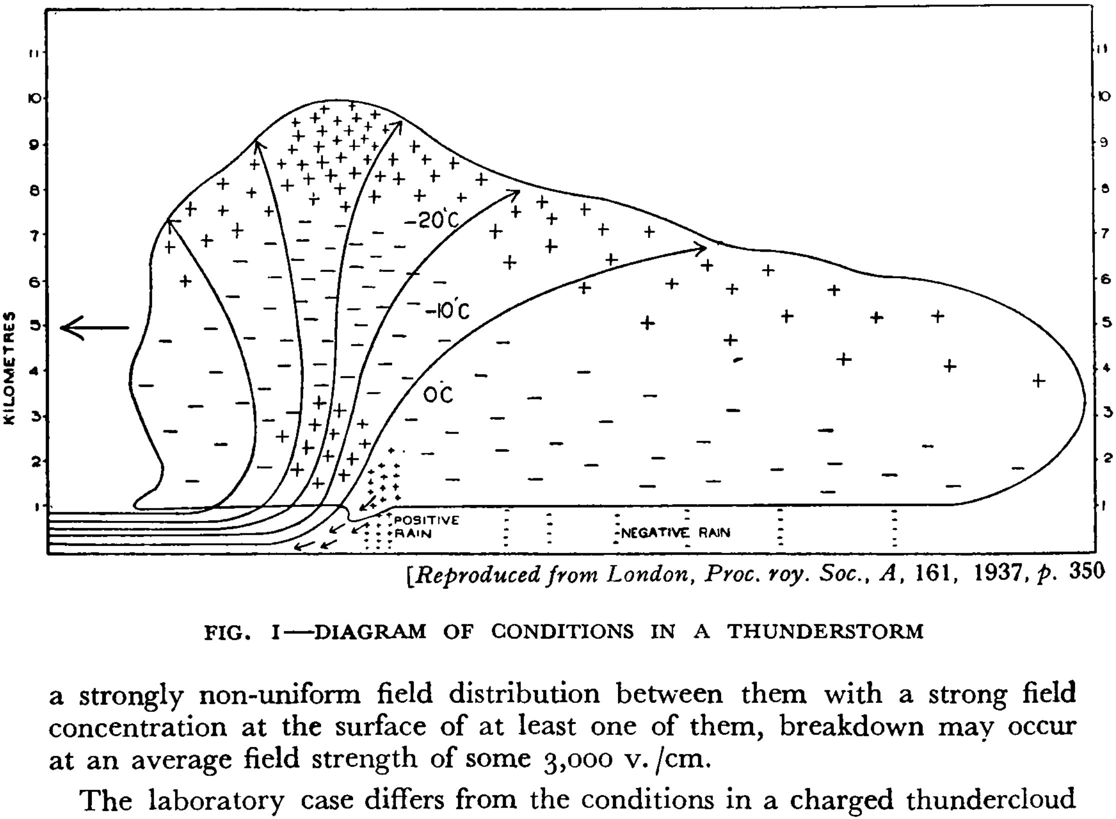
[*] These numbers refer to the list of references on p. 285.

the line of charge separation coinciding roughly with the 0°C. isotherm. The concentrated region of positive charge near the lower edge of the cloud, although frequently present, may be absent.

While this charge distribution can be regarded as fairly well established the mechanism underlying the charging process is still a matter of controversy. All that can be claimed with some degree of certainty is the observation that the charging process is bound up with the development of ice crystals, and that the rate of charge generation is so rapid during the mature stage of the thunderstorm cell as to re-establish within a matter of seconds the large electric charges which may be removed as the result of a lightning flash.

A potential difference—or what is basically the same, a charge separation—between two metallic electrodes in the laboratory is known to produce an electric discharge in the form of a spark if the electric field strength in the space between the electrodes reaches a value of about 30,000 v /cm. If the two electrodes are widely separated and if their shapes are such as to produce a strongly non-uniform field distribution between them with a strong field concentration at the surface of at least one of them, breakdown may occur at an average field strength of some 3,000 v. /cm.



[*Reproduced from London, Proc. roy. Soc., A*, 161, 1937, *p*. 350

FIG. 1—DIAGRAM OF CONDITIONS IN A THUNDERSTORM

The laboratory case differs from the conditions in a charged thundercloud in more than one respect. Thus the cloud is a poor conductor, the atmosphere in a cloud is more or less saturated with water drops of varying size, and the atmospheric pressure is reduced below that at the earth's surface. It has been shown by Macky[5] that an electric discharge may be started in an atmosphere containing water drops at a field strength of about 10,000 v./cm., but even this value exceeds the average field measured in the region below the thundercloud by a factor of about 30 to 100.

The possibility of the propagation of an electric discharge in such weak electric fields was first suggested by Toepler[6, 7]. In support of this suggestion he performed a simple experiment which is worth recalling even if it is not exactly analogous to the lightning discharge. Between two glass plates A and B (see Fig. 2) two tin foils are placed such that a central strip between the glass plates is left free. A potential is applied across the two tin foils thus producing a high electric field strength in the centre region of the outer glass surface. If a water drop is now placed in a position D an electric discharge is initiated both in an upward and downward direction, and with increasing potential difference between the tin foils the discharges grow right up to the edges of the plate, i.e. far into a region which, prior to the occurrence of the discharge itself, was practically free from any electric field. Such a discharge can be called " self-propagating ".

In a similar manner a lightning discharge may be assumed to be initiated when a local field strength of about 10,000 v./cm. is reached at the surface of a single water drop or ice crystal, or an accumulation of such drops or crystals, and when the average field strength throughout the surrounding atmosphere is sufficient to sustain a self-propagating discharge. According to Bruce[8] the field strength required for such a lightning discharge is of the order of 200–300 v./cm., a value which agrees with field observations, the only lower limit of this gradient being that necessary to maintain an arc which, under the prevailing conditions, requires a gradient of about 10 v./cm.

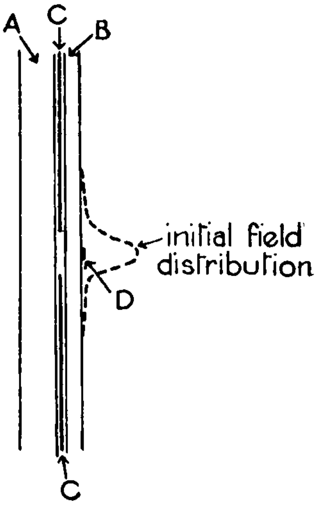


FIG. 2—ELECTRIC SURFACE DISCHARGE AS ANALOGY TO FORMATION OF LIGHTNING DISCHARGE

(after Toepler)

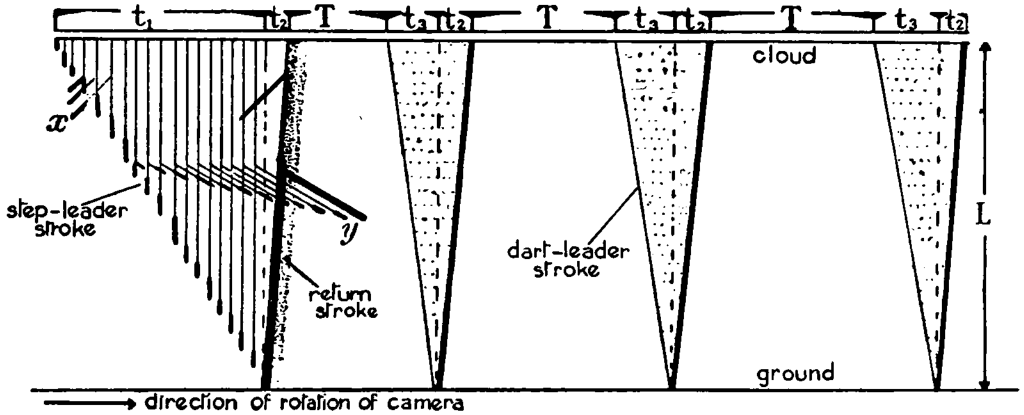
A, B	Glass plates
C	Tin foil
D	Water drop

Applying this mechanism to Fig. 1, three distinct types of lightning discharge are seen to be feasible : a discharge from the bottom of the cloud to earth, a discharge between the positive and negative charges in the same or neighbouring cloud cells, or a discharge from the upper cloud charge into the upper atmosphere. All these types are known to occur although the last-named variety is difficult to observe. A photograph showing cloud-earth and cloud-cloud discharges and a further discharge which may possibly belong to the last-named category is shown in the photograph facing p. 284.

Mechanism of the lightning discharge.—From the historical point of view it is interesting to note that the first ideas on the propagation of the lightning discharge were derived from observations of the laboratory spark.

By using a rapidly rotating camera Walter [9, 10] obtained the photograph facing p. 285. This shows that a spark between two metal electrodes proceeds from both electrodes in several discrete steps with considerable time intervals between the individual steps, each of which is longer than the preceding one. With greatly improved means of recording, this development of the long laboratory spark discharge was later confirmed and elaborated by Allibone and Meek[11].

A more detailed examination of the lightning discharge had to wait for the development of the rotating camera, introduced by Boys, which permits a resolution of time down to about 1 microsecond, and which, in addition, gives a clear indication of the direction of propagation of the discharge phenomenon. From the investigations of Schonland[12] and his collaborators in South Africa with the Boys camera a normal stroke to earth is known to proceed from the cloud in a sequence of steps of almost uniform length and with similarly constant time intervals between successive steps. This development of the leader stroke, as it was termed by Schonland, is shown diagrammatically in Fig. 3. On reaching the earth or a short upward streamer discharge emanating from the earth[13], the faintly luminous leader stroke is followed by the brilliant return stroke which travels upwards towards the cloud with a velocity which, initially, may reach half the velocity of light, but which decreases as the return stroke reaches greater heights above the earth.



[Reproduced by courtesy of the Royal Society

FIG. 3—DIAGRAMMATIC REPRESENTATION OF A MULTIPLE LIGHTNING STROKE TO EARTH

Average values : $t_1 = 0{\cdot}01$ sec. ; $t_2 = 0{\cdot}00004$ sec. ; $t_3 = 0{\cdot}001$ sec. ; $T = 0{\cdot}03$ sec. ; $L = 2$ Km.

In many cases this process comprises the whole lightning discharge. Fifty per cent. of the discharges photographed produce, however, subsequent strokes which normally follow in every detail the course taken by the first stroke, apart from the absence of branching in subsequent component strokes. Furthermore, these subsequent strokes start with a leader which covers the distance from cloud to earth in one " dart ", which is then followed by a return stroke of the same type as that in the first stroke. This process may be repeated several times and up to 42 components have been reported. From a statistical examination[14] of the quantitative information available lightning strokes are known to show the same mechanism all over the world, although it should be noted that our more detailed knowledge is at present confined to negative lightning flashes ; the positive flashes which are known to occur in temperate regions are almost completely absent in South Africa.

An exception to this picture has been observed at the Empire State Building in New York where McEachron[15] found the normal lightning process to be initially reversed. More often than not, the leader stroke starts from the top of the building developing upwards towards the cloud in the same general manner as does the normal leader towards earth. However, on reaching the cloud the leader is not followed by a return stroke, but by a much weaker continuing discharge. This type of discharge is of particular interest because there are reasons to believe that it also describes the typical cloud-cloud discharge which cannot be readily photographed but which appears to consist of a stepped leader stroke without subsequent return stroke. If in the case of the Empire State Building the first stroke is followed by further strokes, these revert to the normal mechanism with downward dart leaders and subsequent upward return strokes.

For an explanation of the stepped leader process Bruce[8] makes use of a phenomenon which had already been suggested by Toepler[7] who had investigated it extensively in the electrodeless spark discharge along an insulating surface. This starts as a diffused brush discharge which suddenly changes into a concentrated arc discharge when a given current value is exceeded. As an arc discharge is governed by a negative current/voltage characteristic the leader discharge progresses, on this theory, towards earth in the form of a streamer or brush discharge until transition to the arc state occurs, a process which is repeated at regular time intervals as the discharge channel lengthens.

An alternative theory has been advanced by Schonland and extended by Loeb and Meek[16]. According to this conception the degree of ionization in a given length of channel decreases due to recombination and the resulting field strength increases until breakdown occurs, thus initiating a further step which, in turn, produces further ionization in the step streamer. This theory, however, has been strongly criticized[8].

Radiation produced by the lightning discharge.—In addition to the photographic evidence mentioned so far, equally valuable information on the lightning discharge has been deduced from the electric field changes produced by a lightning flash. Assuming a point charge q at a height H above a conducting plane, the electric field intensity at a horizontal distance y from the projection of the point charge on the plane is

$$e = \frac{2qH}{(H^2 + y^2)^{3/2}} = \frac{M}{r^{3/2}}$$

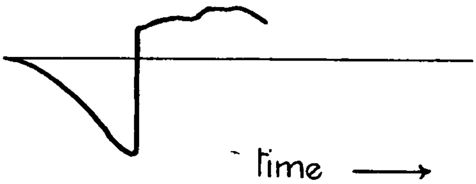
where M is called the electric moment of the charge and r is the distance between the charge and the point of observation. If the charge q is suddenly lowered to a height h above the plane the resulting field change at the earth's surface is

$$E = 2q \left[\frac{H}{(H^2 + y^2)^{3/2}} - \frac{h}{(h^2 + y^2)^{3/2}}\right]$$

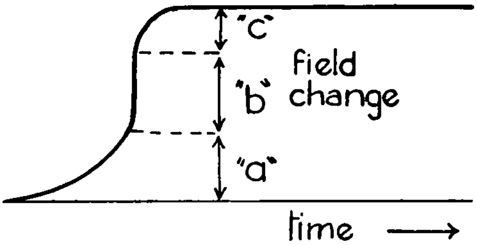
From oscillographic records[17, 18] of the field changes produced by a lightning flash information can be obtained on the movement of electric charges during the development of the lightning discharge.

From such evidence the lightning leader stroke is found to be accompanied by a lowering of some of the electric charge stored in the thundercloud, i.e. in the case of a discharge from the negative charge at the bottom region of the cloud it lowers negative charge into the atmosphere below the cloud. By electrostatic induction the corresponding amount of positive charge collects in the earth underneath the down-coming leader stroke. When the leader contacts earth a violent neutralization results between these two charges of opposite polarity, and this leads to the negative charge in the leader stroke being completely discharged into the earth. Frequently, although not invariably, this period is followed by a further gradual lowering of negative charge from the cloud along the highly ionized lightning path.

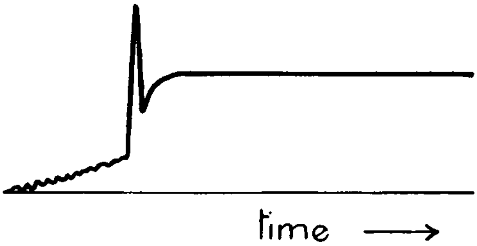
The correlation of these three stages with the corresponding field changes, i.e. the gradual " a " field change with the slow leader process, the rapid " b " change with the violent return-stroke process, and the slow " c " field change with the gradual removal of some of the remaining charge in the cloud was first suggested by Appleton and Chapman[17] and later convincingly established by Schonland[18]. Typical records obtained[19] at two different distances between observer and lightning stroke are shown in Figs. 4(*a*) and 4(*b*).



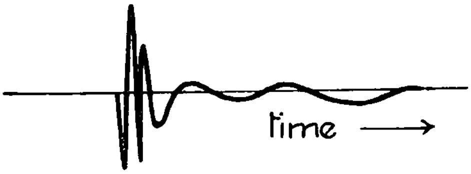
(*a*) approximate distance 5 Km.
(after Malan and Schonland)



(*b*) approximate distance 10 Km.
(after Appleton and Chapman)



(*c*) approximate distance 50 Km.
(after Appleton and Chapman)



(*d*) approximate distance 400 Km.
(after Appleton and Chapman)

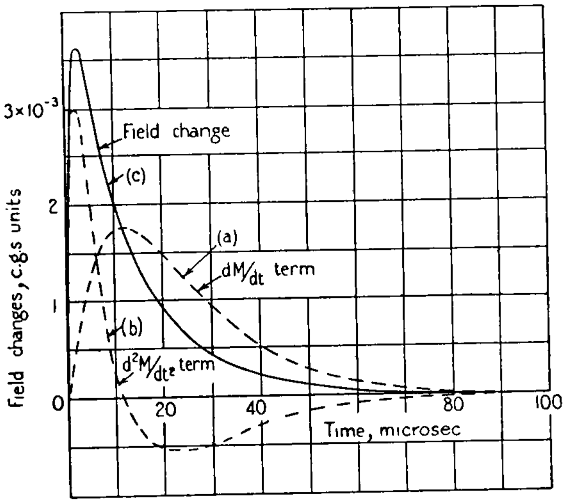
FIG. 4—ELECTRIC FIELD CHANGES DUE TO A LIGHTNING STROKE AT DIFFERENT DISTANCES
(not to scale)

In order to describe the total field change caused by a lightning stroke at any distance the above expression for the electrostatic field change has to be replaced by

$$e = \frac{M}{r^3} + \frac{1}{cr^2} \times \frac{dM}{dt} + \frac{1}{c^2r} \times \frac{d^2M}{dt^2}$$

in which c is the velocity of light and in which the second and third terms represent the induction and the radiation field changes respectively. As these last two terms are the first and second differentials of the electric moment M, the time variation of which is best indicated in Fig. 4(*b*), the induction and radiation terms may be expected to produce oscillatory field changes and these are in fact observed[20-23] at great distances (see Figs. 4(*c*) and 4(*d*)) where the radiation term becomes increasingly predominant over the electrostatic term.

Fig. 4 permits some interesting conclusions to be drawn on the movement of charges during the lightning process. Thus the " a " field change shows a smooth shape at short distances from the lightning stroke (Fig. 4(*a*)) but superimposed oscillations indicative of a radiation field at greater distances (Fig. 4(*c*)). As these latter can be shown to be associated with the fast discrete steps in the first leader stroke the current involved in the step process must be small compared with that of the return stroke. In fact the smooth field change recorded at close distances affords strong support for Schonland's suggestion that the steps in the leader stroke are superimposed on a continuously moving " pilot leader " which is too faint to be photographed. Such a pilot discharge had already been suggested by Walter to precede the stepped streamer formation of a long spark such as is illustrated in the photograph facing p. 285.

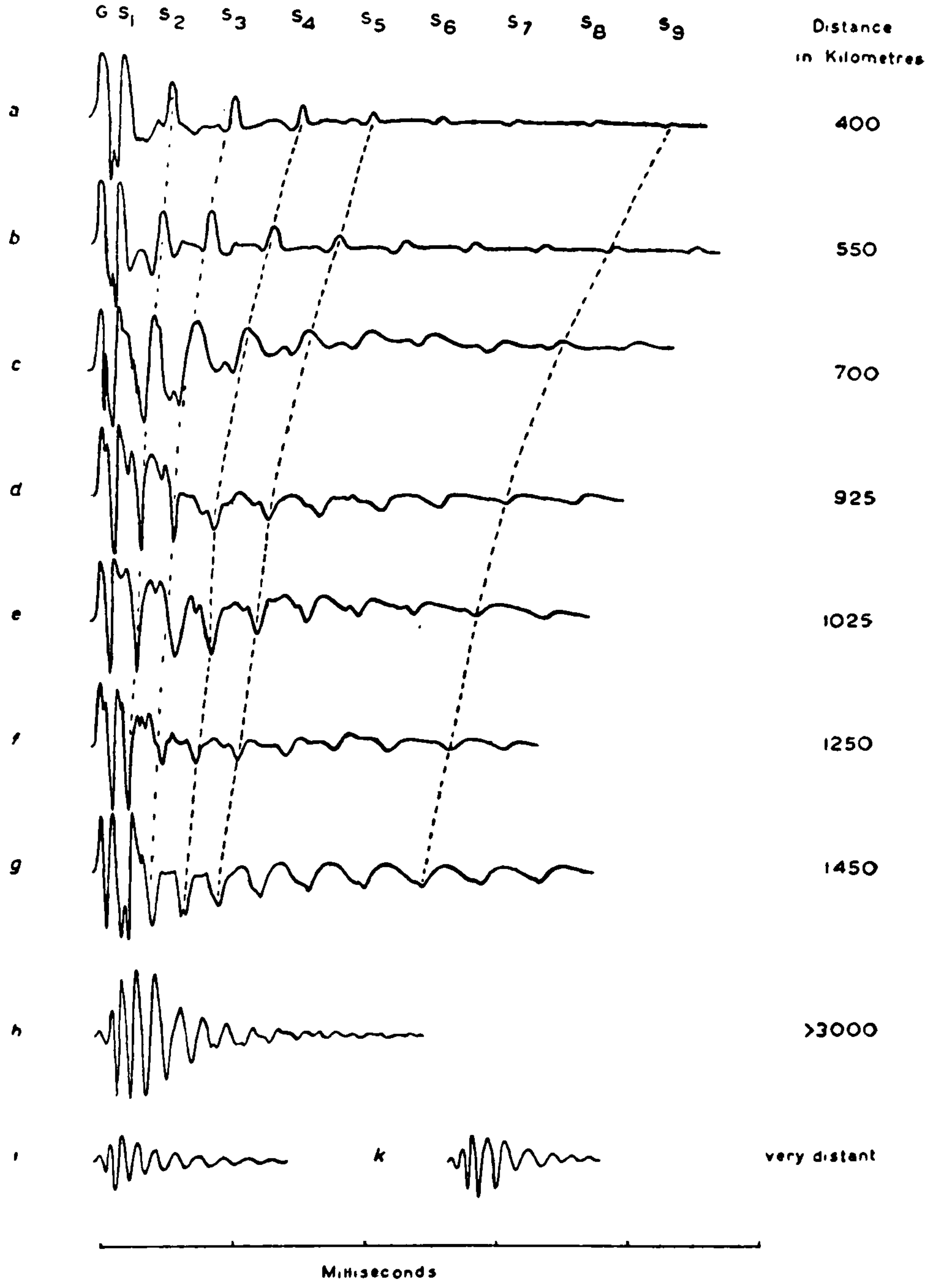


[*Reproduced by courtesy of the Institution of Electrical Engineers*

FIG. 5—CALCULATED INDUCTION AND RADIATION FIELD CHANGES DUE TO A LIGHTNING STROKE AT A DISTANCE OF 3 KM.

The absence of radiation field changes in the " c " portion indicates that a lightning flash to earth is not normally accompanied by any other type of rapid discharge in some other part of the cloud. This observation is of importance because it has been suggested that the visible part of the lightning discharge to earth is, of necessity, linked with a simultaneous upward discharge from the cloud centre tapped towards the upper oppositely charged region of the cloud. Whether the upper positive charge of a bipolar cloud may, as the result of a stroke to earth, be discharged in a continuous type of discharge towards the upper atmosphere remains at present a conjecture.

Turning now to the " b " field change, this is seen from Fig. 4 to give rise to a strong oscillatory radiation which becomes increasingly predominant with increasing distance from the lightning stroke. The effective short circuit between the negative charge in the leader channel and the bound positive charge in the ground below initiates, as already mentioned, an intense process of recombination of the two charges, and this results in a current pulse of high amplitude flowing upwards along the lightning channel. This current pulse



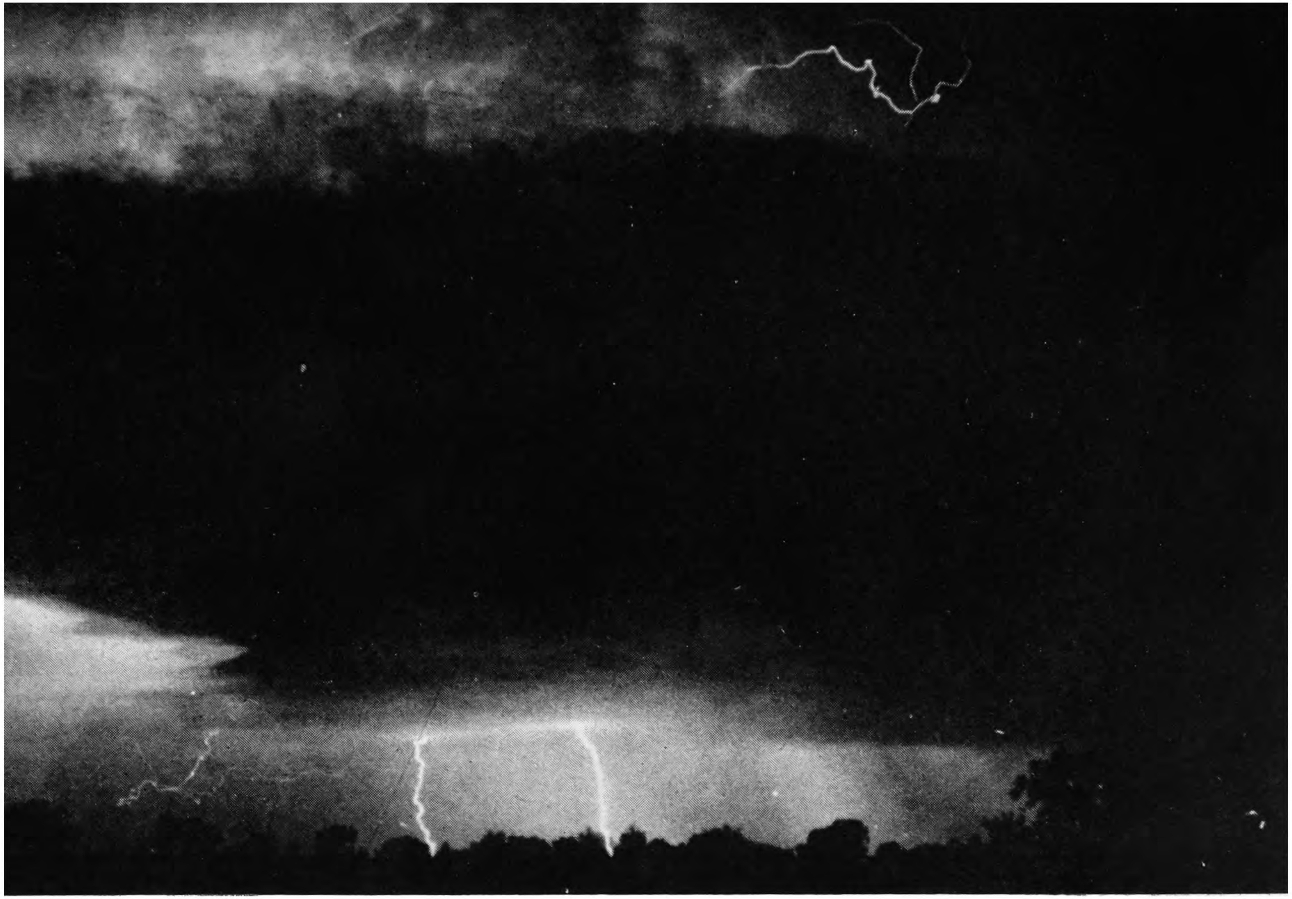
[*Reproduced by courtesy of the Royal Society*

FIG. 6—ATMOSPHERIC WAVE FORMS AT DIFFERENT DISTANCES FROM A LIGHTNING STROKE

may reach a value up to 160,000 amp. with an average value of about 20,000 amp., and has a double-exponential wave shape which rises to its peak in about 5 microseconds, and falls to a small value in about 100 microseconds. This shape can be expressed by

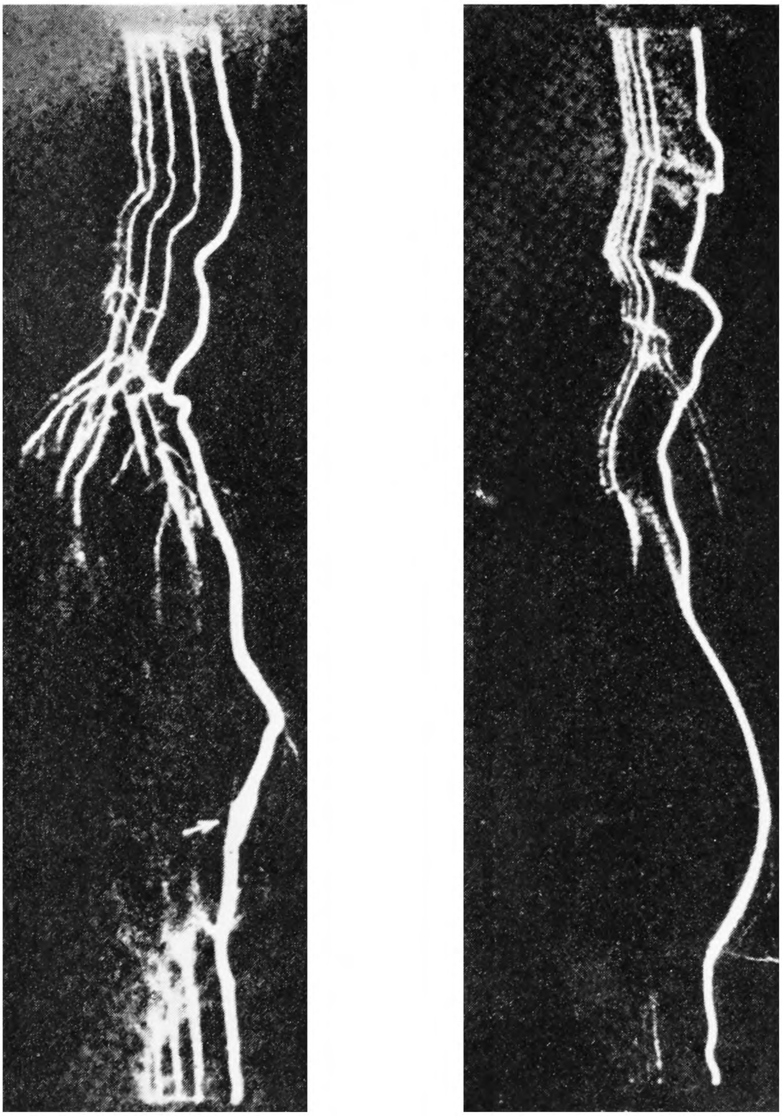
$$i_L = i_{max} \left(e^{-at} - e^{-bt}\right)$$

where $a = 4{\cdot}4 \times 10^4$ and $b = 4{\cdot}6 \times 10^5$.



LIGHTNING PHOTOGRAPH AT SPRINGSURE, QUEENSLAND
(See p. 279)

[*To face page* 284



Reproduced from Ann. Phys., Leipzig, **66**, 1898, *p.* 636

PHOTOGRAPH OF LABORATORY SPARK (8 CM. LONG) TAKEN WITH A ROTATING CAMERA

(See p. 280).

From observations with the Boys camera the velocity of the return stroke is found to be described by the expression

$$v = v_0 \, e^{-\gamma t}$$

where the initial velocity is $v = 8 \times 10^9$ cm./sec. and $\gamma = 3 \times 10^4$. The velocity v is measured in centimetres per second if t is given in seconds.

If the return stroke current is now visualized as a current flowing in a conductor of progressively increasing length, and at any instant of constant amplitude along the appropriate length of channel the inductive field change can be seen[14] to be

$$E_m = -\frac{2}{cr^2} \frac{i_L v_0}{\gamma} \left(e^{-at} - e^{-bt}\right) \left(1 - e^{-\gamma t}\right)$$

In this way the induction and radiation terms of the field change can be evaluated from the known characteristics of the lightning current. The result of a calculation of the field change is shown in Fig. 5 from which the radiation field at a distance of 3 Km. is found to produce a single oscillation of an equivalent duration of several tens of microseconds. It was first suggested by Laby[24] that the atmospheric wave resulting from such a pulse should consist of a ground or direct pulse followed by a series of discrete reflections of this pulse from a conducting layer in the ionosphere. A detailed investigation of this phenomenon by Schonland and collaborators[25] in which up to 30 such reflections were recorded is reproduced in Fig. 6 in which the gradual merging of the ground and reflected pulses into an oscillatory wave pattern is clearly shown. These measurements proved in fact so accurate as to provide valuable information on the height of the reflecting layer and its variation with time.

As compared with the foregoing strong radiation fields produced by a lightning stroke to earth, the rapid field changes produced by a lightning flash within a thundercloud are confined to the much weaker effects of the step-leader stroke by which such a discharge is initiated.

It is thus established that the oscillatory wave pattern which gives rise to the atmospheric disturbances described as " sferics " is the result of the intense return stroke of a lightning discharge to earth and that all thunderstorms within about 4,000 miles of the observing station are potential sources of these atmospheric disturbances.

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CENTENARY OF MESSRS. NEGRETTI & ZAMBRA

1850–1950

By P. N. SKELTON

The celebration this year of the Centenary of one of the most famous firms of meteorological instrument makers, Messrs. Negretti & Zambra, is an occasion for looking back on their history, and, indeed, on the beginning of meteorological instrument making on an industrial scale in this country.

The firm of Negretti & Zambra was founded by Henry Negretti and Joseph Warren Zambra on April 24, 1850 at 11 Hatton Garden, London.

Henry Negretti, born on November 13, 1818, at Como, Italy, was the son of Paolo Negretti who is reputed to have owned and driven a service of carriage vehicles over the St. Gotthard pass. His son, Henry, left Italy and came to London when he was about twelve. Whether or not it is true that he and his ultimate partner, and also Casella and Hicks, learnt the trade of thermometer making from Caesar Tagliabue, who, apparently also came from Como and established himself in Brooke Street, Holborn, in 1769, it is difficult to say. What is certainly true is that by 1840 he was established at 20 Greville St., Hatton Garden; that by 1844 he was a junior partner of Mrs. Jane Pizzi at 19 Leather Lane, Hatton Garden, and that by 1845 he was established at the same address on his own account.

It is also certain that Joseph Warren Zambra, who was born in London in 1822, was by 1847 a junior partner of John Tagliabue, and that the Tagliabue family was very prominent in the instrument trade in its early days.

With the foundation of the firm of Negretti & Zambra in April 1850 success was immediately achieved. The original partnership, the deed of which is still in existence, was for 10 years, 1850–60, but this was renewed in 1860 for a further 21 years, being unfortunately interrupted, however, by the death of Henry Negretti in 1879. Both families were represented continuously in the firm until 1935, when Mr. Mark Zambra retired, after which his family has not taken an active part. The family of Negretti still continues to be strongly represented. In 1946, after 96 years as a partnership and after becoming one of the largest private concerns in the country, the firm became a private company, and in 1948 a public company.

Just after its foundation the firm received considerable impetus from the Great Exhibition in Hyde Park in 1851 where a Prize Medal was awarded to them. The instruments shown at this Exhibition were : " Standard open cistern barometer, self-registering barometer, pocket sympiesometer, Rutherford's thermometer, Sixe's self-registering thermometer, hygrometers ". Negretti & Zambra were appointed Meteorological Instrument Makers to Queen Victoria and similar appointments followed from the Royal Observatory, Greenwich, and the British Meteorological Society (now the Royal Meteorological Society).

The association of Negretti & Zambra with the Meteorological Office began as soon as the Office was formed, instruments being purchased as early as 1858. In that year, for instance, twelve " Barometers for Fishermen " were bought and it is interesting to note that five of these are still in use and in good condition, namely at Lybster, Mousehole, Newhaven, Nairn and Filey. The early records of the Office also show purchases of a variety of other instruments from the firm.

In 1851 Negretti & Zambra patented a maximum registering thermometer which was a great improvement on existing types, and which is the type now in almost universal use for maximum and clinical thermometers. Negretti & Zambra made the aneroid barometer used by Glaisher in his balloon experiments, when, on September 5, 1862, he reached a height of seven miles.

During the hundred years of its existence the firm has occupied a large number of premises of which the most familiar, to the general public, was that at 38 Holborn Viaduct. These premises were destroyed by bombing on December 29, 1940. The Head Office is now at 122 Regent Street, the premises being acquired from John Newman, philosophical instrument maker in 1862.

Negretti & Zambra's production has not been confined only to meteorological instruments. Optical instruments were produced from 1909 until just after 1918 when it was decided to concentrate on the manufacture of industrial and aeronautical instruments. Boost and pressure gauges were then developed for the Air Ministry, and a patent mercury-in-steel transmitting thermometer was put on the market. This instrument is used in the form of a recorder for dry and wet bulbs by the Naval Weather Service, and at some of the land stations of the Meteorological Office. Pressure sensitive elements made by Negretti & Zambra are very widely used for the barometer units in radiosondes. In 1925 a department for the manufacture of electrical instruments was set up, and the firm continues to expand in many branches of instrument making.

Acknowledgments are due to the Editor *Instrument Practice* and to Negretti & Zambra, Ltd. for the loan of the blocks of the photographs facing p. 300, and for permission to make extracts from an article in the May issue of that publication, entitled " Negretti & Zambra—1850–1950 ".

USE OF THE HODOGRAPH IN ESTIMATING THE RAINFALL AT FRONTS

By J. M. CRADDOCK, M.A. and D. PRITCHARD

In a recent article by Parker[1]* a method is put forward for estimating the rainfall at warm and cold fronts, based on the argument that if the wind in the warm air relative to that in the frontal surface has a component towards the frontal surface, then upsliding must be taking place, whereas if the airflow in the warm air has a component away from the frontal surface, there must be downsliding. This method is also referred to by Penner[2], and must be fairly well known. Its theoretical basis depends on its being permissible to treat the frontal surface as a plane boundary moving without change of form, and is thus rather insecure, but it is nevertheless worth while to test the practical value of the method by trying it on a representative body of data in a straightforward and unsophisticated way. This has been done by applying it, as far as possible in the way suggested by Parker, to every eligible warm or cold front which passed Aldergrove during the two winter seasons, October 1947–March 1948 and October 1948–March 1949, and for which the observational data were available.

Warm front.—For the method to be applicable, the front must intersect the upper air sounding at a level which is not too near the surface and yet not too high. Hence the fronts considered were any which were between roughly 100 and 300 miles from Aldergrove at the time of the upper air sounding, and for each of these, 21 in all, the wind hodograph was drawn, using the data in the *Daily Weather Report*, and the direction of the surface front shown, as suggested by Parker. An attempt was made to identify the frontal transition zones by finding a zone in which the wind shear was parallel to the surface front, but was not very successful, as many of the hodographs had no such zone. Another criterion, that the frontal transition zone is a zone of relatively great wind shear and of wind veering with height separating zones above and below in which the shear is less, was effective in every case, although even here the upper or lower limit of the transition zone was uncertain in a few cases. The wind shear in the zone so defined was usually backed from a direction along the line of the surface front (with warm air on the right), the average value of the highly variable angle of backing being perhaps 20–30°. Further, the lower limit of this zone did not agree with, but generally lay above the upper limit of the cold air as found from the temperature soundings. The upper limit of the cold air, which is defined by Parker to be the level of the front, was used in all that follows, and was taken to be the most obvious kink on the temperature sounding below an inversion or zone of reduced lapse rate, without reference to cloud or humidity data. It is a level which cannot easily be identified from the hodograph alone, and which does not generally agree with the lower limit of the frontal zone as shown by the wind data.

Accepting as frontal level the upper limit of the cold air, the normal wind at that level (i.e. the component of the wind at that level normal to the surface direction of the front) is plotted in Fig. 1 against the actual speed of the front. This speed was found as accurately as possible in the way illustrated in Fig. 2, by plotting against time the displacements of the front between synoptic hours

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* The index numbers refer to the list of references given on p. 292

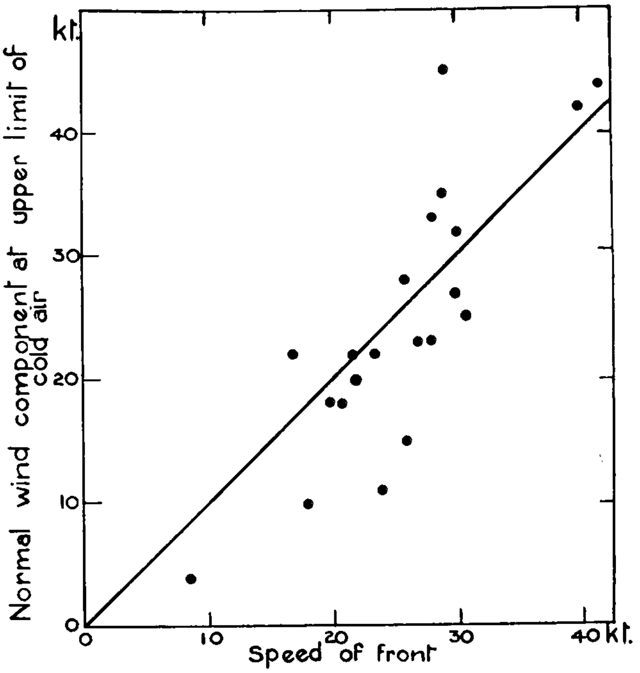


FIG. I—SPEED OF WARM FRONT COMPARED WITH NORMAL WIND COMPONENT AT THE UPPER LIMIT OF THE COLD AIR

(the positions being taken from the 3-hourly working charts of the Central Forecasting Office, Dunstable) and finding the slope of the line of best fit, estimated by eye. Fig. 1 shows that there is in fact a strong association between the variables, the correlation being 0·78, and that there is no apparent tendency for the normal wind to be greater or less than the actual speed of the front. It seems, therefore, that the method used by Parker for estimating the speed of a warm front from an upper air sounding is a fairly good one. It is doubtful whether it is better than linear extrapolation when the position of the front has been fixed on several earlier charts, but should prove useful when earlier frontal positions are uncertain.

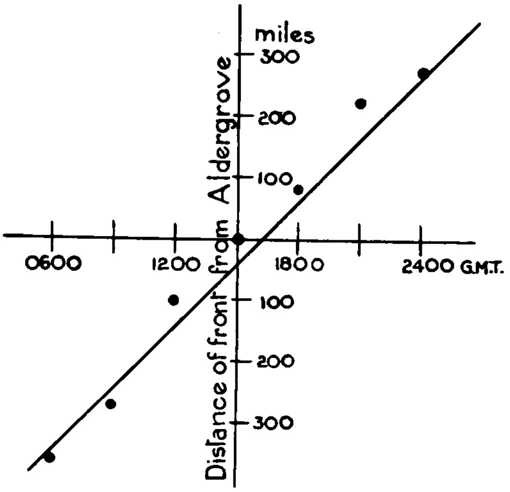
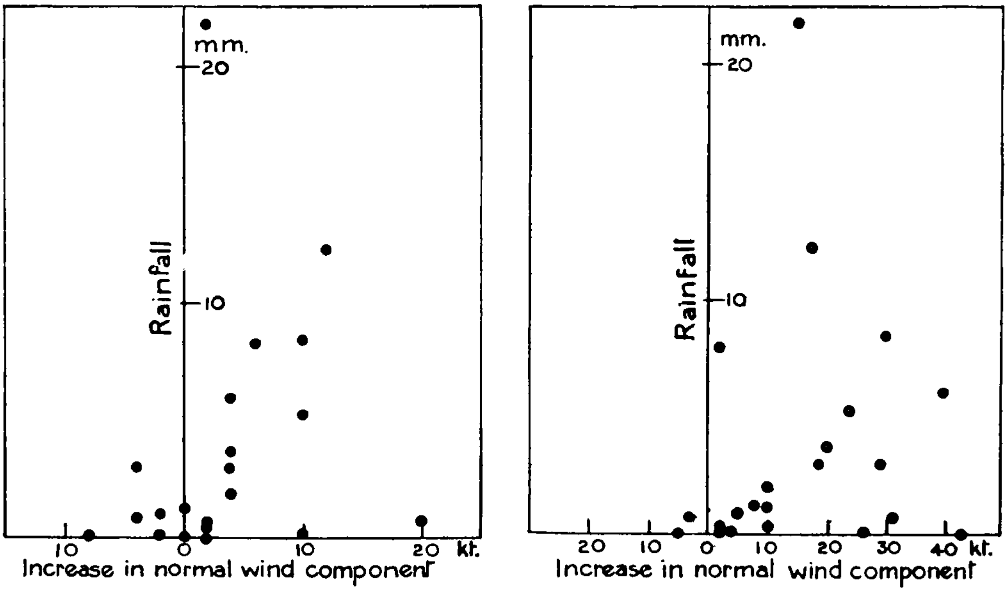


FIG. 2—ESTIMATION OF SPEED OF WARM FRONT

Distances were measured at each synoptic hour along the normal drawn from the position of the front at the time of the upper air sounding.

The increase or decrease of the normal wind above the frontal level is *prima facie* associated with vertical motion in the warm air, and provides the proposed estimate of the intensity of frontal rain. It is uncertain whether regard should be had to vertical motion only in the frontal zone, or to that in the warm air as well, so two measurements were made, of the increase or decrease of normal wind in the 100-mb. layer above the level taken for the front, and the increase for the whole layer from the front up to 400-mb. These values are plotted in Fig. 3 against the rainfall associated with the front, a mean value found from the hourly records of four stations in Northern Ireland (Aldergrove, Armagh, Ballykelly and Castle Archdale). Both these graphs show some association between the variables, and there is not much to choose between them. The correlation would not justify the use of the method for the numerical estimation of rainfall, but would support a qualitative statement, perhaps as follows : if the normal wind in the 100-mb. layer above the front is decreasing with height, then little or no rain is to be expected (average amount about 1 mm.), but if the normal wind is increasing with height, considerable rain may fall (average amount about 5 mm.).



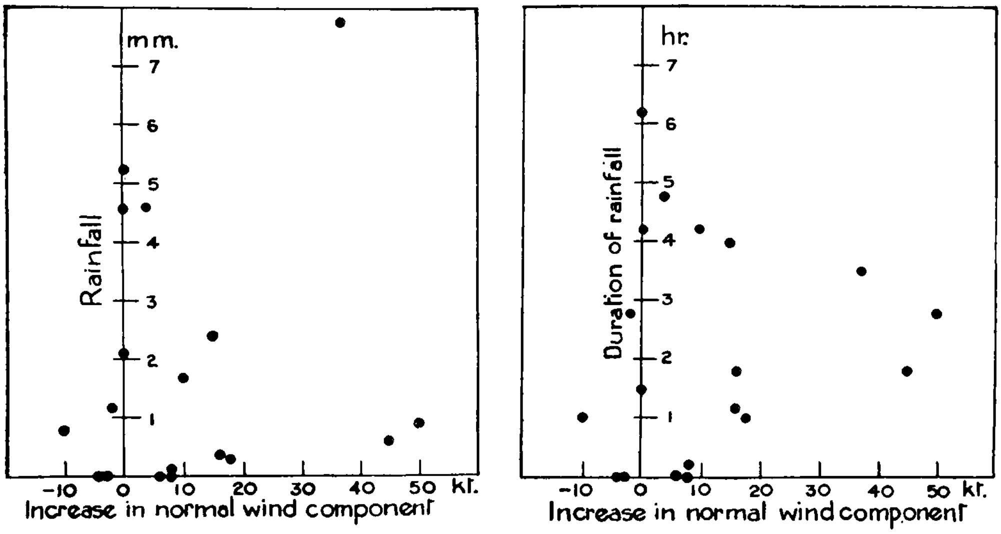
(*a*) estimated by means of the shear in the normal wind component in the 100-mb. layer immediately above the upper limit of the cold air.

(*b*) estimated by means of the shear in the normal wind component in the layer between the upper limit of the cold air and the 400-mb. level.

FIG. 3—RELATION BETWEEN RAINFALL AMOUNT AND UPSLOPE MOTION AT THE WARM FRONT

This association suggested that perhaps the intensity of rainfall depended on the intensity of the front as such, but a test, made using as measure of the intensity of the front the mean wind shear in the direction of the front from the frontal level up to 400-mb., did not reveal any association.

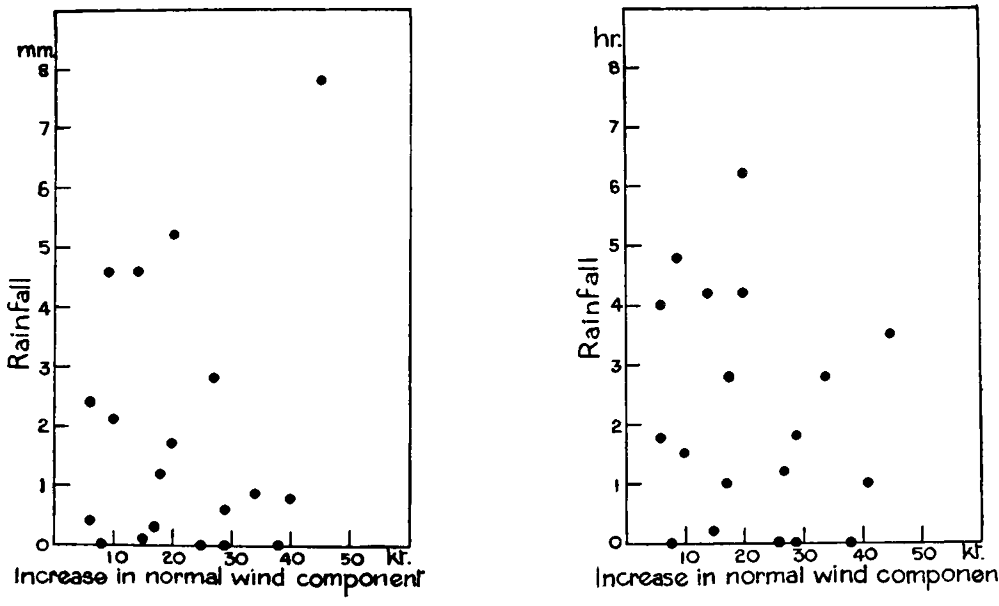
Cold front.—It is not possible to treat a cold front in quite the same way as a warm, because an upper air sounding which intersects the frontal surface will lie behind the front, and be available, generally, only after most of the frontal rain has already fallen. The estimate, to be of value, must be made before the front reaches the station concerned. So in this case the test was made, for the two winter seasons, on every upper air sounding at Aldergrove



(*a*) amount of rainfall. (*b*) duration of rainfall.

FIG. 4—RELATION BETWEEN RAINFALL AT COLD FRONTS AND THE INCREASE IN THE NORMAL WIND COMPONENT IN THE 500–300-MB. LAYER

which lay ahead of but within 200 miles of an approaching cold front. There were 19 of these, and the hodographs were drawn as before. These soundings lie wholly within the warm air, and there is no obvious argument for deciding on the layer in which the normal wind shear may be expected to represent the air flow up or down the frontal slope. Two alternatives were tried, the 500–300-mb. layer and the 950–400-mb. layer. The normal wind shear, which usually increased with height, is plotted against the amount and duration of frontal rain in Figs. 4 and 5. In none of these is there any noticeable association between the variables, so that the present evidence does not suggest that the method is of value for estimating the intensity or duration of rainfall at cold fronts.



(*a*) amount of rainfall. (*b*) duration of rainfall.

FIG. 5—RELATION BETWEEN RAINFALL AT COLD FRONTS AND THE INCREASE IN THE NORMAL WIND COMPONENT IN THE 950–400-MB. LAYER

[I was very interested to see the foregoing check of my method. However, as was pointed out in the original paper it is not possible to use the method to give an accurate quantitative estimate of actual rainfall since the stability of the warm air must also enter into the calculation, and it is not easy to allow for this quantitatively. The value of the method lies in its ability to indicate that rain will break out on a front which may not be giving rain at the time.

In the case of the cold front, I feel that the check was done in too unsophisticated a manner. Cold fronts fall into three definite classes : (i) those in which the normal wind decreases with height in the warm air above the frontal surface causing much cloud and rain behind the front ; (ii) those in which there is little change in normal wind with height, in this case the cloud occurs mainly in the warm air just ahead of the front and appears to be caused by a convective cell concentrated along the front ; and (iii) those in which there is a marked increase of normal wind with height and consequently results in no rain as a rule. It follows that the rainfall cannot depend on the normal wind except in cold fronts of type (i). I found that it is possible in practice to use the method to forecast outbreaks of rain behind cold fronts when the front was not previously giving any rain.—A. E. PARKER]

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ABLATION IN THE SCOTTISH HIGHLANDS

By D. L. CHAMPION
Assistant Director, Snow Survey of Britain

During the month of July 1949, the Durham University Exploration Society established a camp on the Ben Macdhui massif in the Cairngorms under the leadership of Mr. P. F. Green, from which the then extant snow-beds were surveyed and daily observations of the ablation were made on one of the larger beds. Standard thermometers and screen, etc., were set up near the camp, and these instruments were read at the fixed hours 0900, 1500 and 2100 G.M.T. each day.

The area covered by the survey included the mountains, Ben Macdhui, Braeriach, and Cairngorm, and extended as far south as the river Dee, to Beinn A' Bhuird in the east and Loch Einich in the west. Some 35 snow-beds were found of total area exceeding 320,000 sq. yd.

Fig. 1 shows the location of the snow-bed from which the observations of ablation were obtained, together with the site of the meteorological instruments set up near the camp above Coire Sputan Dearg. The extent of the snow-bed can be judged from Fig. 2, which shows one of the party walking across it. The ablation was measured by means of graduated poles which were hammered vertically into the snow, the fall in level being read off each day. It is assumed that the snow had well settled and any shrinkage of the mass during the period under observation has been ignored.

The period covered by the observations was from July 10 to July 27, a total of 18 days, and the observed ablation is shown in Fig. 3, together with the daily mean temperature. It will be seen that, as one would expect,

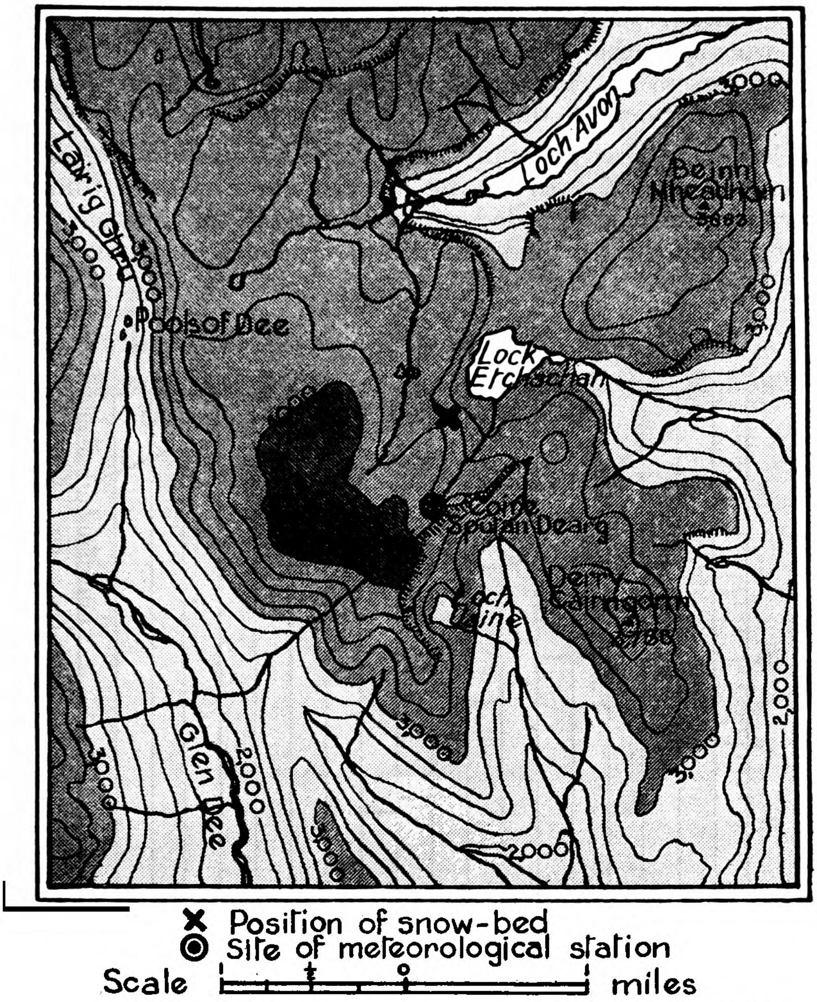
Loch Avon
Beinn Mheadhoin
3883
Lairig Ghru
3000
Pools of Dee
Loch Etchachan
Coire Sputan Dearg
Loch Uaine
Derry Cairngorm
3788
Glen Dee
2000
× Position of snow-bed
◉ Site of meteorological station
Scale
½
0
1
miles

FIG. I—POSITION OF SNOW-BED IN THE GRAMPIANS
The contour heights are given in feet.

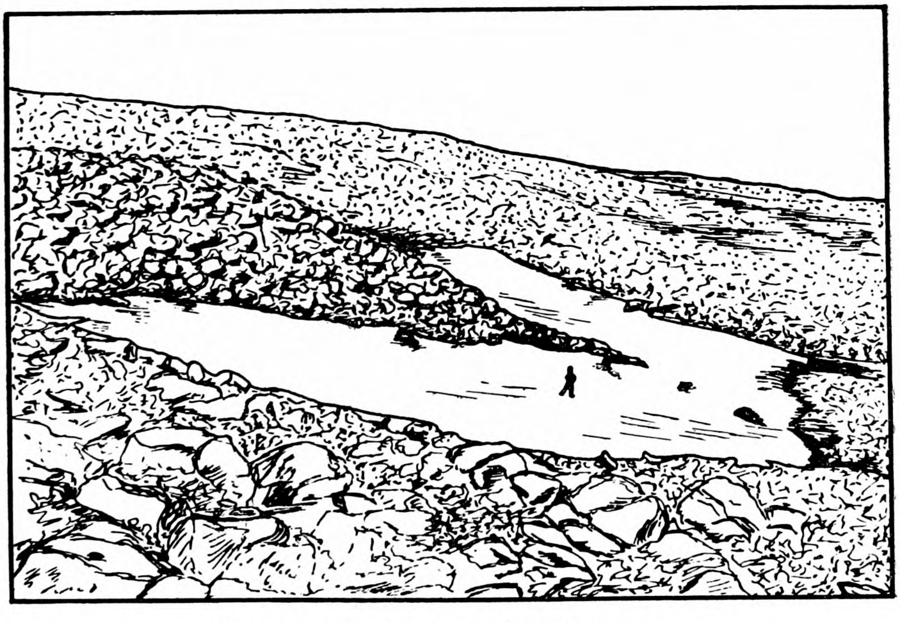

FIG. 2—EXTENT OF THE SNOW-BED

the rate of ablation tends to follow the mean temperature, the least daily ablation of 1·0 in. on the 19th coinciding with the lowest mean temperature of the period, i.e. 36°F. The greatest ablation occurred on the 22nd when the snow surface fell 6·7 in., the mean temperature on this day being 54°F.

The whole period was generally cloudy, with considerable hill fog, only the 10th, 21st, 24th and 27th having a mean cloudiness less than 7 oktas; and measurable rain was recorded every day except on the 10th, 17th, 23rd, 24th and 26th, the total rainfall for the period being 1·56 in.

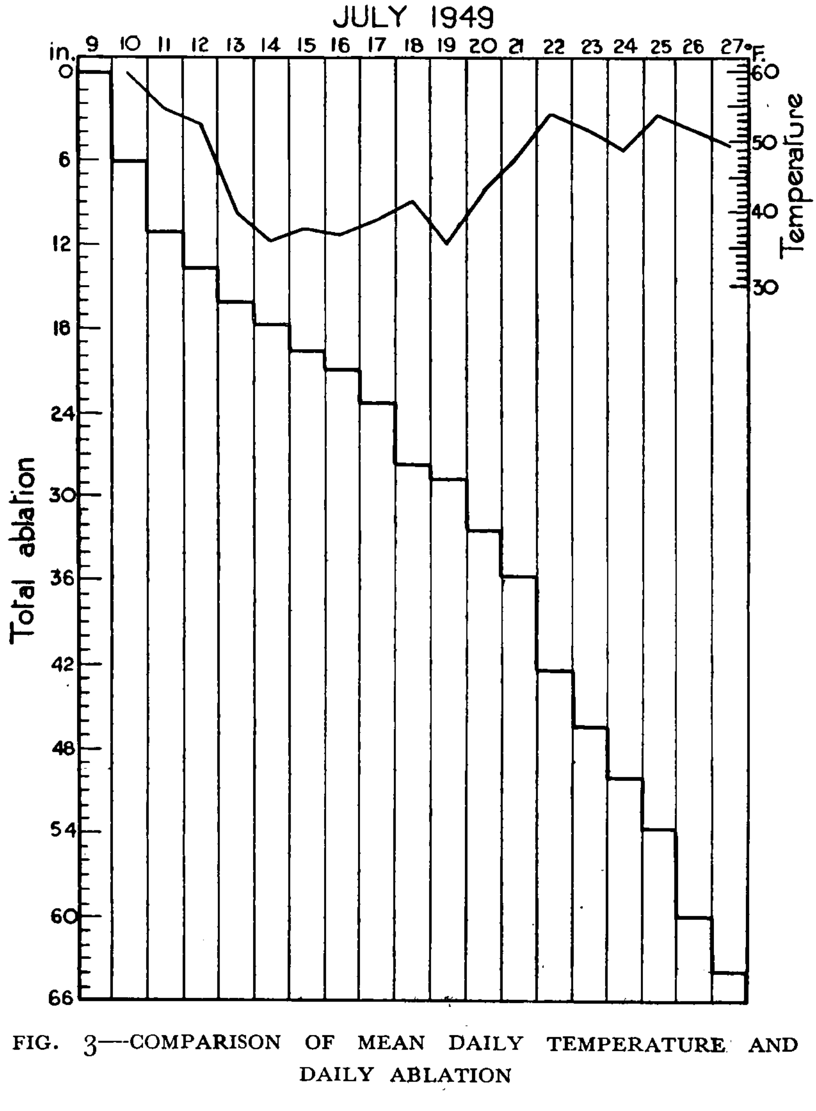

FIG. 3—COMPARISON OF MEAN DAILY TEMPERATURE AND DAILY ABLATION

The mean relative humidity was consequently high, only falling below 90 per cent. on the 10th, 12th and 19th. The total ablation during the period amounted to 63·9 in., and if this rate had been maintained it was assumed that the snow-bed would not have persisted throughout the summer.

In summer months by far the greatest factor in ablation is that due to the melting of the snow, and little can be due to direct evaporation from the surface of the snow-bed, particularly when the snow mass is frequently enveloped in cloud.

The relation between daily ablation and mean temperature above the freezing point is shown by the curve in Fig. 4, and can be roughly expressed as

$$A = 0{\cdot}24\ (t-32)$$

where A is the ablation in inches and t is the mean temperature in degrees Fahrenheit. It is of interest to note that the rate of ablation is 0·01 in. per degree per hour, and, assuming this rate was maintained at all the snow-beds examined, the total yield would be over 370,000 gallons of melt water per day. The importance of mountain snow-beds in assisting the flow of rivers used for irrigation, hydro-electric schemes, etc. during dry spells is well brought out by these results.

Further details of mountain snow cover in the British Isles will be found in the *Journal of Glaciology**.

Thanks are due to the British Glaciological Society for kind permission to publish the data.

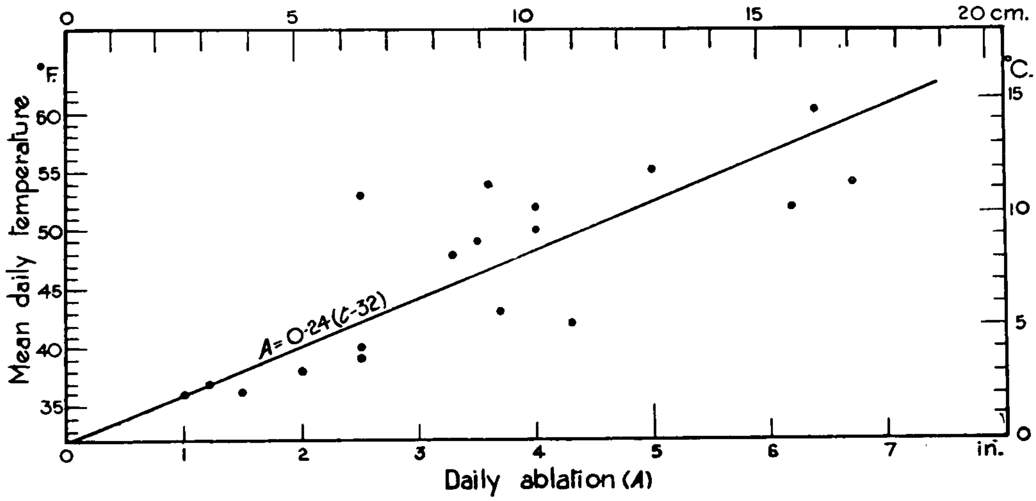

FIG. 4—RELATION BETWEEN DAILY TEMPERATURE AND DAILY ABLATION

VARIATION OF WIND WITH HEIGHT AT LOW LEVELS OVER THE SEA

By A. H. GORDON, M.S.

Introduction.—A brief analysis was undertaken of the variation of wind with height from data derived from pilot balloon ascents made from H.M. ships in Marsden Square 146 in the Atlantic Ocean west of the Bay of Biscay (40–50°N., 10–20°W.). The data covered the period 1937–44 inclusive. The analysis included only those ascents which were comparable level for level so that homogeneity of wind structure could be obtained. Thus the variation of wind between the surface and 2,000 ft. and between the surface and 4,000 ft. were treated separately using all available ascents which reached 2,000 ft. and 4,000 ft. respectively.

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* HAWKE, E. L. and CHAMPION, D. L.; Report on the snow survey of Great Britain for the season 1948–49. *J. Glaciol., London,* **1**, 1950, p. 362.

Mean scalar velocity.—Most of the observations of surface wind velocity in the analysis have been measured by anemometer although a few have been estimated from the state of the sea. The height of the anemometer above the surface of the sea may vary depending on the vessel from which the ascent was made but it is probably of the order of 100 ft. in most cases.

Table I shows the variation of mean scalar velocity with height together with the ratio of the mean velocity of the surface wind to the mean velocity of the wind at 2,000 ft. It is seen that the wind velocity increases a little between the surface and 1,000 ft. and then remains fairly constant. It would seem therefore that the wind at 2,000 ft. closely approximates to the gradient wind. The ratio (mean V_s) /(mean $V_{2,000}$) and mean of $V_s/V_{2,000}$ are higher than the normally accepted values of V_s/V_g. This may be partly due to the fact that the surface wind velocity is referred to about 100 ft. above the sea when it is measured by anemometer but to only 33 ft. when it is estimated. It may also be partly due to the fact that the ascents were limited to days of reasonable visibility when the height of the low cloud base was not below 2,000 ft.

TABLE I—VARIATION OF MEAN SCALAR VELOCITY WITH HEIGHT

	Surface—2,000 ft. 153 cases	Surface—4,000 ft. 81 cases
ft.	kt.	kt.
4,000	..	15·1
3,000	..	14·7
2,000	17·5	15·1
1,000	17·3	14·7
Surface	15·6	13·0
(Mean V_s) /(mean $V_{2,000}$)	0·89	0·86
Mean ($V_s/V_{2,000}$)	0·94	0.91

Ratio of surface to gradient wind at sea.—An analysis of 710 observations, taken at random, of the ratio of the wind at 50 ft. to the wind at 2,000 ft. made aboard ocean weather ships in the North Atlantic gave a mean value of 0·71. Other values of this order for the ratio of surface to gradient wind have been obtained by C. S. Durst[1]*, R. Frost[2] and other meteorologists[3, 4].

Diurnal Variation of $V_s/V_{2,000}$.—Table II shows the diurnal variation of $V_s/V_{2,000}$ when the mean values are grouped at intervals between 0700 and 1900 local time. If the wind at 2,000 ft. can be considered to be inappreciably affected by any diurnal range it is seen that there is evidence of a diurnal range of surface wind velocity during daylight hours which reaches a maximum at or shortly before noon and a minimum in the mid afternoon and early evening.

TABLE II—DIURNAL VARIATION OF $V_s/V_{2\,000}$ DURING DAYLIGHT HOURS

Local time ..	0700–0800	0900–1000	1100–1200	1300–1400	1500–1600	1700–1900
$V_s/V_{2,000}$ ..	0·92	0·99	1·01	0·97	0·82	0·82

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* These numbers refer to the list of references on p. 297.

Mean vector wind.—Table III shows the variation of mean vector wind with height. In each case the wind at 1,000 ft. has veered from the surface wind and increased in velocity. Above 2,000 ft. the mean vector wind has backed and the velocity remained fairly constant.

TABLE III—VARIATION OF MEAN VECTOR WIND WITH HEIGHT

	SURFACE—2,000 ft. 153 cases				SURFACE—4,000 ft. 81 cases			
	Mean vector wind		Variation		Mean vector wind		Variation	
ft.	°	kt.	°	kt.	°	kt.	°	kt.
4,000 ..	..	..	..	..	328	5·3	back 9	−0·2
3,000 ..	..	..	..	..	327	5·5	back 6	+0.1
2,000 ..	327	4·9	back 1	+0·1	343	5·4	veer 4	+0·2
1,000 ..	328	4·8	veer 5	+0·9	339	5·2	veer 15	+0·8
Surface ..	323	3·9			324	4·4		

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1. DURST, C. S.; Relation of surface winds to pressure gradients. *Met. Mag., London*, **78**, 1949, p. 157.
2. FROST, R.; Atmospheric turbulence. *Quart. J. R. met. Soc., London*, **74**, 1948, p. 316.
3. SHAW, SIR NAPIER; Manual of meteorology. Vol. IV. Meterological calculus: pressure and wind. Cambridge, 1931.
4. GORDON, A. H.; The ratio between observed velocities of the wind at 50 feet and 2,000 feet over the North Atlantic Ocean. *Quart. J. R. met. Soc., London*, **76**, 1950, p. 344.

OFFICIAL PUBLICATIONS

The following publications have recently been issued:—

Annual Report of the Director of the Meteorological Office presented by the Meteorological Committee to the Secretary of State for Air for the year April 1, 1949 to March 31, 1950.

This report contains an account of the work of the State Meteorological Service. Much of the work is directed towards meeting the day-to-day needs of the public, the Royal Air Force, the Merchant Navy, Civil Aviation, other Government Departments, and various industrial concerns and public utility services.

The pressing need for research is not overlooked, however, and the expansion of research into forecasting problems has been manifested during the past year by the establishment of the Napier Shaw Laboratory at Dunstable. At other establishments studies are being made of the physics of clouds and size of cloud droplets, using radar methods and aircraft equipped with instruments specially developed for the purpose. Other investigations include the sampling of air at great heights, turbulence at high levels, and the visibility of airport approach lights from the air. At the geophysical observatories, Kew, Eskdalemuir and Lerwick, records are maintained of the standard meteorological elements, radiation, terrestrial magnetism, atmospheric electricity, and seismic movements.

The increasing effort devoted to meteorological problems in agriculture is reflected by the introduction of a separate section in the Report describing activities in co-operation with the National Advisory Service of the Ministry of Agriculture and the special problems which are being studied for the benefit of agriculture. Another service instituted during the past year is a daily broadcast by television from London and Birmingham of meteorological charts and forecasts covering south-east England and the Midlands.

Assistance was given to the Meteorological Services of Ceylon and Persia by training members of the staff of those Services. Radio-sonde and radar-wind equipment was supplied to New Zealand, the Falkland Islands, and Hongkong.

The Report concludes with reference to international meetings of the International Meteorological Organization, the International Civil Aviation Organization, and the International Union of Geodesy and Geophysics, which were attended by senior members of the staff of the Meteorological Office.

METEOROLOGICAL REPORTS

No. 6—Equivalent Headwinds—application of upper wind statistics to air-route planning. By J. S. Sawyer, M.A.

The planning and operation of air routes through different climatic regions of the world requires a knowledge of the winds likely to occur on particular routes and their effect on the pay-load which can be carried by the aircraft. This report presents a method by which the available meteorological statistics regarding the free atmosphere may be adapted to provide the information required by the aircraft operator in a form in which he can use it.

The report gives the theoretical basis of the statistical treatment and also discusses the accuracy of the results. A comparison of the theoretical calculations with the practical results on two air routes is also given.

No. 7—Equivalent headwinds on some of the principal air routes of the world

This report gives the average equivalent headwind for a number of air routes of the world. An equivalent headwind is the difference between air speed and ground speed averaged throughout a flight. Separate values are given for each route for the four seasons and for every 10,000 ft. from 10,000 to 40,000 ft. The routes are for the most part those flown regularly by British aircraft.

Also given are figures for determining the headwind (greater than the average) which the aircraft must be able to meet in order to achieve a definite regularity of service. For example, on the route Karachi to Cairo at 40,000ft. in winter, the average equivalent headwind is 89 kt. If an 85 per cent. regularity of service is desired, the aircraft must be able to meet a headwind of 109 kt., and for 90 per cent. regularity, 113 kt.

The report should be of considerable use for long-term planning by regular air-route operators, by charter companies and by anyone planning to fly an aircraft overseas.

LETTER TO THE EDITOR

Rainbow without visible precipitation

At about 1935 G.M.T. on May 20, 1950, a rainbow was seen from Tunbridge Wells without visible precipitation. The sky was nearly covered with low fracto-cloud of indefinite type. The clouds in the north-west were strongly illuminated. Opposite there developed a strong primary bow with well marked colours and spurious bows of total width on the left of the arch as wide as the bow. There was a trace of a secondary bow. No rain was falling at the place of observation and there was no definite sign of virga from the clouds.

CICELY M. BOTLEY

2 Park Road, Tunbridge Wells, June 10, 1950

[Presumably the rainbow was formed in very fine droplets too small to be seen from the ground and which evaporated before reaching it. There was a feeble occlusion moving eastwards over south-east England on the evening of May 20, giving slight local rain.

Observations of rainbows without visible precipitation are scarce. Such a rainbow was seen by Mr. E. L. Hawke in 1934* with only cirrostratus cloud. A German observer, K. Glass† who kept a systematic watch for the phenomenon, saw it four times in five years. On three of the occasions reported by Glass the cloud state was similar to the one reported by Miss Botley and on the fourth there were 8 tenths of cirrostratus nebula above low fractostratus. —Ed. *M.M.*]

NOTES AND NEWS

Weather information from British whalers in the Antarctic

Merchant shipping has once more played a considerable part in aiding Antarctic exploration. The whaling fleets of several nations have supplied weather information, from the Antarctic Ocean, to the joint Norwegian-British-Swedish Expedition to Queen Maud Land. Amongst these fleets were ten vessels, owned by two British Whaling Companies, Messrs. Chr. Salvesen and Co., Ltd., and the United Whalers, Ltd. Recruited by the Marine Branch of the Meteorological Office, these vessels have, in co-operation with the Meteorological Bureau of South Africa, rendered assistance to the Expedition by voluntarily taking synoptic weather observations and transmitting their reports to " MET PRETORIA " for relay to the Expedition's base in the Antarctic mainland, during the 1949–50 whaling season.

Whaling is carried out on a highly competitive basis ; and individual companies do not care to give away their position of operation to their competitors. Accordingly, Norsk Polarinstitutt (co-ordinating authority for the Joint Antarctic Expedition) prepared a separate cypher for each company, to be used in conjunction with the international weather code FM 21. The Meteorological Bureau of South Africa and the Expedition in the Antarctic were each in possession of all cyphers.

An event of historic meteorological interest resulted from this widespread scheme. Sufficient weather information was obtained from the Antarctic to issue daily during the whaling season, a special Antarctic inference for the benefit of the whalers. This inference was prepared and issued by the Naval Weather Service at Simonstown at the request of the South African Meteorological Bureau.

Slotted sunshine recorder

One of the difficulties experienced at stations lies in changing the sunshine card after sunset or before sunrise each day during summer when the sun does not set until a late hour. Private observers do not meet with this difficulty to the same extent as stations manned by staff who cease duty at the end of the normal working day, but even so it would often be an advantage to be able to change the card each day at some convenient hour before sunset.

The difficulty has now been overcome by the design of a sunshine recorder, similar in all respects to the Meteorological Office Mk.II instrument but with slots, wide enough to take a sun card, cut through the summer-card section of the bowl at positions corresponding approximately to 0830 and 1530 L.A.T., when the card is in its normal position.

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* HAWKE, E. L. ; A rainbow in cirro-stratus. *Met. Mag., London*, **69**, 1934, p. 65.

† GLASS, K. ; Regenbogenbildung ohne Niederschlag. *Z. angew. Met. (Das Wetter), Leipzig*, **55**, 1938, p. 404.

The method of working is as follows : at a convenient time of the day after 1530 L.A.T. (which may vary, in the British Isles, from about 4.20 p.m. to 5.10 p.m. B.S.T. according to the longitude of the observing station and the date) the card is withdrawn, from its normal position, in the direction in which the burn is progressing, until the " morning " end of the card just uncovers the slot cut through the afternoon section of the bowl at a position corresponding to approximately 1530 L.A.T.

To record the evening sunshine, the card is pushed back again so that most of the used portion passes through the slot to the back of the recorder bowl, the card being positioned correctly by placing a specified hour line on the card against a mark on the bowl.

At the same time a new card to receive the next morning's record is inserted in the normal groove at the other end of the bowl and allowed to project through the slot cut at about 0830 L.A.T. to the back of the bowl. This card is also positioned against a mark on the bowl.

Next day, at some convenient time before 0830 L.A.T. the card with the complete day's record on it is removed for measurement and the card with the morning record on it is withdrawn and replaced in the normal position in the recorder, care being taken to position it correctly against the mark on the bowl.

A clamping screw at each end of the groove prevents movement of the cards.

The Instruments Supply branch of the Meteorological Office now holds stocks of " slotted " sunshine recorders and is prepared to supply private stations, Health Resort stations and others which make reports to the Office under approved conditions. The cost of the recorders complete with a year's supply of cards is £30 9s. 5d., exclusive of the cost of a packing case and transportation. The cost of the case, however, would be credited in full, if returned carriage paid in good condition to the Meteorological Office, Headstone Drive, Harrow.

At present the slotted recorders are only available for use in the United Kingdom.

C. JOWETT

Loss of the French O.W.S. *Laplace*

It is with great sorrow that we record the tragic loss of the French O.W.S. *Laplace* which was blown up while at anchor in the Baie de la Fresnaie, near St. Malo, during the night of Friday, September 15, 1950. As a result of this explosion which is believed to have been due to a magnetic mine, 22 men were killed or drowned, 29 are missing, and 41 are known to have been rescued. The Captain of the *Laplace* is among the missing. Our readers will wish to join us in expressing our sympathy with the relatives of those who lost their lives.

The *Laplace* was a frigate of about 2,000 tons displacement and about 300 ft. in length, operated by the French Navy as an ocean weather ship in the North Atlantic, having been bought from the United States and specially fitted up in France for this work. Two other French ships of a similar type engaged on this duty are the *Mermoz* and *Le Brix*. The *Laplace* was one of a unique international fleet of vessels engaged upon humanitarian

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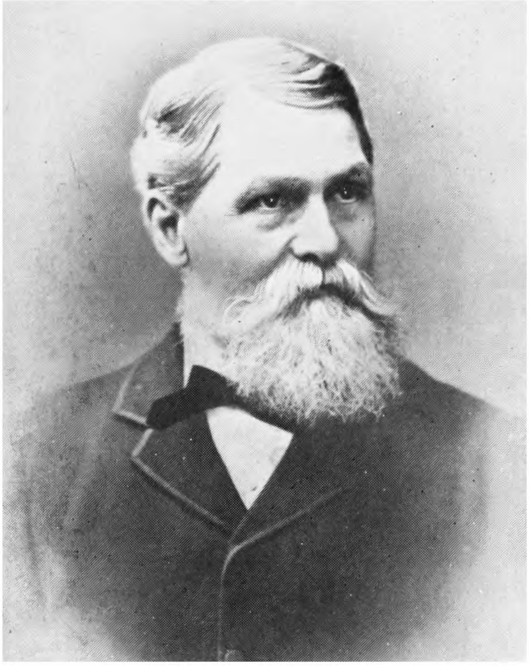
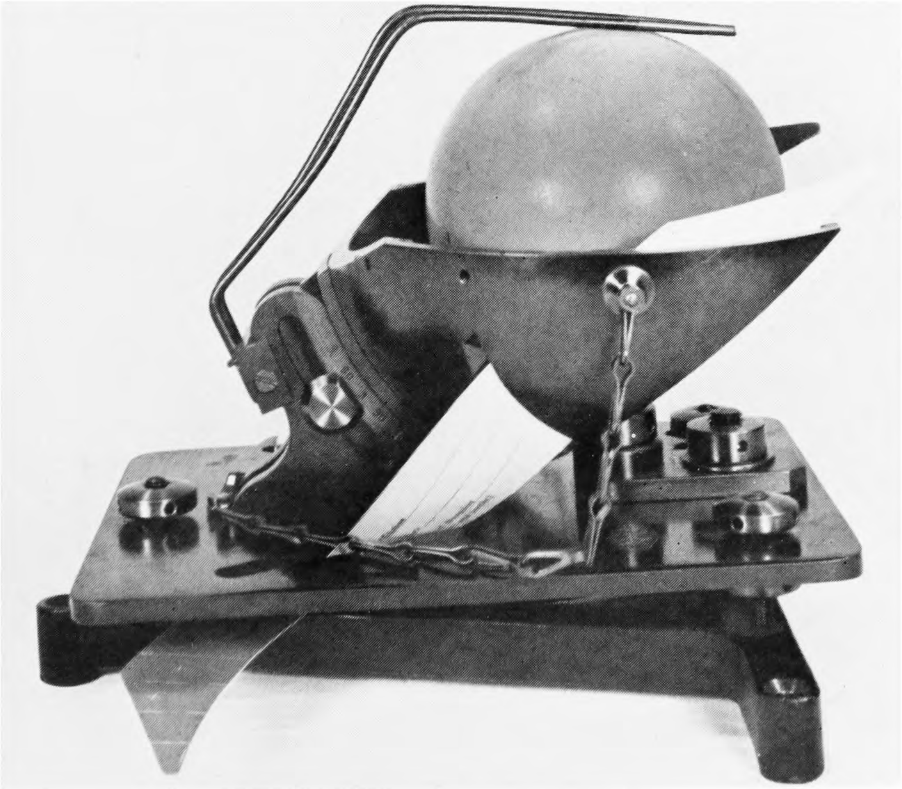
HENRY NEGRETTI
(See p. 286)



Reproduced by courtesy of "Instrument Practice"

JOSEPH WARREN ZAMBRA
(See p. 286)



SLOTTED SUNSHINE RECORDER

To face page 301]

FRENCH O.W.S. *Laplace*

and scientific work of considerable importance to all the countries bordering the North Atlantic. Her loss in peace time due to a relic of war time, besides involving French lives and French property, is a loss to international science.

The *Laplace* had only recently completed a period of 21 days duty at station KING, situated at position 45°N., 16°W. (in the Bay of Biscay). She was relieved at that station by the *Mermoz* on September 13. She had returned to Brest and was on her way to St. Malo to represent the French Navy at the opening of new harbour works. Being delayed by bad weather, her Captain decided to anchor in the Bay until daylight, rather than risk entering the harbour during dark hours. The disaster occurred about midnight when most of her crew were asleep, and the vessel sank within five minutes. These facts probably account for the large loss of life.

As an epitaph to an ocean weather ship, it is not perhaps unfitting to record her last coded synoptic message :—

SHIP K (FMMK) 140005/Z

SYNOP SHIP =

50452 15100 22822 97020 12616 22400 15300 05311 12945 =

Noctilucent clouds on the night of June 30–July 1, 1950

Noctilucent clouds were observed on the night of June 30, 1950 from Mildenhall, Suffolk, Wyton, Huntingdonshire (both lat. 52°20′N.), Pinner, Middlesex, (51°35′N.), Forest Hall, Northumberland (55°01′N.), and Workington, Cumberland (54°39′N.).

The Meteorological Office staff at Mildenhall saw the clouds from 2200 G.M.T. until midnight. They were within an irregular segment of a circle from 340° to 355°. The brightest patch was at an elevation of 5°. The colour was bluish-white with an occasional yellow tinge. Similar observations were made by the Wyton staff.

The clouds were observed from Pinner by Dr. Tor Bergeron, who had seen such clouds before from Sweden, and Mr. G. A. Bull at 2300 G.M.T. on a bearing of 350° and at an elevation of 3–4°. They were silvery-yellow below and bluish-white above. Mr. A. J. Acfield at Forest Hall and Mr. W. B. Housman at Workington saw two main streaks of bright blue-green light, half a degree in width and separated by half a degree stretching for 30° horizontally over the twilight glow 10° above the horizon and with bright blue-green cloudlets below. The display faded about midnight. No bright lines were seen in the spectroscope*.

Calculation from the elevations assuming a height of 60 miles, shows that the clouds were in latitude 58–59°N., that is they were over northern Scotland. Unfortunately the sky was too cloudy over Scotland for Mr. J. L. Paton's observing team (see *Meteorological Magazine*, December 1949, p. 354) to see them.

We are indebted to the Editor of *British Astronomical Association Circulars* for permission to include Mr. Acfield's and Mr. Housman's observations.

REVIEWS

Grundfragen der Wetterkunde. By Hellmut Berg. C. E. S. Bücherei, **31**. 7½ in. × 4½ in., pp. 172, *Illus*. Curt E. Schwab, Stuttgart, 1949. *D.M.* 4.80.

Prof. Berg's latest book appears in a series, " die C. E. S. Reihe ", corresponding to the British " Pelican " books. It gives a brief semi-popular description of a good deal of meteorology assuming very little mathematical or physical knowledge, in a very readable style.

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* For further details see *British Astronomical Association Circulars*.

There is an historical introduction. The major part of the book is divided into five parts :—

I. Physical bases. This part deals with the main elements, pressure, temperature, wind and their measurement.

II. Structure of the atmosphere, describing the temperature and chemical constitution of the atmosphere up to the ionosphere.

III. Clouds and precipitation, covering condensation processes, cloud classification and structure, artificial rain, and thunderstorms.

IV. Synoptic meteorology, with elementary dynamical meteorology, weather charts, air masses and fronts, solar effects on the weather, and the föhn.

V. Weather forecasting, a very brief sketch of methods of short, medium and long-range forecasting. The latter parts are concerned mainly with Baur's " stratospheric steering " ideas.

The best part of the book in the reviewer's opinion is Part III. Very recent researches, such as Seaton's estimations of ionospheric temperature and the American artificial precipitation trials of 1948, are mentioned in places. The book, however, as seems to be usual with this author's works, is rather unbalanced. A relatively great deal of space is devoted to such matters as the propagation of sound in the high atmosphere and the existence of free sodium there, but the pages on synoptic meteorology are concerned only with depressions and fronts and avoid anticyclones. Radiation is scarcely mentioned, and fog appears merely as a sub-class of clouds, " Outgoing-radiation clouds ", with no description of the various ways in which it is formed or its prediction.

There are fourteen excellent cloud photographs at the end of the book. The diagrams of Figs. 47 and 49 are interchanged.

G. A. BULL

Weather Lore. By Richard Inwards. Revised by E. L. Hawke. $8\frac{1}{2}$ in. × $5\frac{1}{2}$ in. pp. 252. *Illus.* 4th edition. Published for the Royal Meteorological Society by Rider and Company, London, 1950. 12*s.* 0*d.*

The third edition of Richard Inwards' collection of proverbs, sayings and rules concerning the weather was published in 1898. It has long been out of print and had become an expensive rarity on second-hand book shelves. The fourth edition is therefore certain of its welcome. It will make a treasured addition to the home libraries of meteorologists and antiquarians, and contains much to take and hold the attention of the general reader.

Richard Inwards, a former president of the Royal Meteorological Society, died in 1937 and bequeathed to the Society the copyright of "Weather Lore". The Council of the Royal Meteorological Society invited Mr. E. L. Hawke, M.A., F.R.A.S., a vice-president of the Society, to prepare this fourth edition for publication during the Society's centenary year—an action which would certainly have met with the approval of the author who had for so many years been the father of the Society.

Such a compendium as Richard Inwards' required little revision on the part of the present editor. He has aimed at inserting occasional annotations where he thought present-day knowledge would add to the interest. These annotations are sometimes open to contention but are full of general interest. The modern meteorologist will, however, be disappointed to find that no effort has been made to link at least a few of the sayings with synoptic situations, and will no doubt regret that this opportunity has been missed. Weather forecasting has undergone three fairly well defined phases. The first was built on experience—an era of weather signs, a linking of optical phenomena and winds with ensuing weather. The second was an instrument era founded on the work of Robert Hooke. This was the period of barometers and thermometers, a period which has added its own quota to the store of weather sayings and which the present edition does well to incorporate. The third is the era dependent upon rapid communications—the synoptic era. It would have been stimulating to all to have seen the lessons learnt from the last phase applied to the findings of the earlier phases, and to have seen those predictions for these islands extending beyond periods of two or three days firmly contradicted.

A small number of sayings which Inwards probably inserted in order to preserve them, but which contain no reference to the weather, have been omitted. These are far outnumbered by the additions which include Buchan's cold and warm periods and some Welsh weather lore.

The reviewer was surprised to find the popular saying

Rain before seven
Fine before eleven

divorced from the final couplet :—

Rain after two
Rain the day through.

Both couplets form part of the whole in the lore of the Welsh border country. He was also surprised to discover the Welsh weather lore now included to be completely foreign to him.

Other changes include the omission of those tables of dubious accuracy listing plants which should bloom on certain saints' days ; the addition of a few supplementary items found in Inwards' handwriting on one of his own copies of an earlier edition ; and an excellent preface and a biographical note on Richard Inwards by the present editor.

The volume as it stands is probably the finest of its nature, representing as it does in essence the observations, deductions, and experiences of farmers, sailors, naturalists and all men who through the ages have been subjected to the vagaries of a " temperate " climate. Like the earlier edition it contains an excellent bibliography and subject index. It is attractively bound and the Royal Meteorological Society and the editor are to be congratulated on their work.

G. J. EVANS

OBITUARIES

H. N. Warren, O.B.E.—By the death of Mr. Warren, Director of the Australian State Meteorological Service, meteorologists the world over, and particularly those in the British Commonwealth of Nations, have lost an able and loyal colleague.

Herbert Norman Warren was born at Melbourne on April 6, 1888, and was educated at the University of Melbourne. In 1914 he joined the Public Service and entered the Department of Home Affairs of Victoria. During the first world war he served as a Company Commander with the Australian Forces, having previously served with the Victoria Scottish Regiment from 1906 to 1908. After the war he returned to the Public Service, in which he held a number of appointments, the most important being that on the Board for the organization of Australian Commonwealth Departments. The experience which he there gained was to stand him in good stead when he was attached to the Meteorological Branch in 1938 to organize it for aviation and defence. In 1939 he was made Assistant Director (Administration), and the following year he became Director.

During the second world war he played an active part in connexion with the Allied operations in the south-west Pacific. He was Director of the Allied Meteorological Services in that Theatre and held a staff appointment at Allied Air Force Headquarters. He attended conferences at Batavia, Singapore and Auckland, and became Chairman of the Meteorological Committee set up at G.H.Q., South-west Pacific Area, in 1943. He held the rank of Group Captain in the Royal Australian Air Force, and was awarded the O.B.E. for his services.

Since the end of the war Mr. Warren continued to play an active part in international meteorology. He attended the Conference of Directors held in London in February 1946, and was a prominent figure at the Conference of Empire Meteorologists which immediately followed. As President of Regional Commission V of the International Meteorological Organization he took the lead in standardizing meteorological procedures in the South-west Pacific Region. He was present at the meetings of the International Meteorological Organization Commissions at Toronto in 1947 and at the Conference of Directors which followed in Washington. At the latter meeting he played an important and effective part as chairman of the committee responsible for drafting the Convention for the new World Meteorological Organization. The last task that he performed was to attend the meeting of the Executive Council of the International Meteorological Organization at Lausanne in May of this year, and it was during the course of this meeting that he was taken seriously ill. After resting for a while in a local clinic, he came back to England at the end of June, and almost immediately left by boat for home. He was destined, however, not to reach Melbourne, but died on the ship at Adelaide on August 5.

Those who had the good fortune to know Mr. Warren recognized in him a man of strong character and robust common sense. His independence of thought made him the champion of any cause which he regarded as worthy of support, and his sense of fairness earned for him the respect of all. Those of us who met Mrs. Warren at Toronto or in this country in 1947 will wish to offer her our profoundest sympathy in her loss.

N. K. JOHNSON

Mr. Arthur Burnet.—Many readers will learn with regret of the death of Mr. Arthur Burnet who, in 1942, at the age of 63, joined the staff of the Meteorological Office in order to take a share in the war effort. After working on the harmonic analysis of pressure as part of an experiment in long-range forecasting, he joined the newly formed Upper Air Section and worked at Stonehouse and Harrow until his resignation in October 1946. Up to a few months ago he was a familiar figure at scientific meetings.

METEOROLOGICAL OFFICE NEWS

Ozone observations.—In 1947, at the instigation of the Gassiot Committee of the Royal Society, plans were made to resume regular observations of atmospheric ozone at a network of stations in the United Kingdom. To this end, modern ozone spectrophotometers of the Dobson type have recently been supplied to the upper air units at Camborne and Downham Market, while Aldergrove and Lerwick are to be similarly equipped later. Ozone measurements are to be made normally twice a day, near to the time of routine radiosonde ascents.

This project is part of a wider scheme, sponsored by the International Meteorological Association, to obtain ozone measurements by a standard procedure at a number of stations in Europe and neighbouring areas so that the distribution and variation of ozone, which reaches maximum concentration between heights of 20 and 30 Km., may be investigated in relation to the meteorological situation. The upper air information now available, which is more abundant and more reliable than before the war, should facilitate these researches.

Examination successes.—We offer congratulations to the following on their recent successes :

(1) Mr. R. J. Ogden and Mr. P. M. Shaw, who have obtained the B.Sc. (Special) degree of London University in mathematics with second class honours.

(2) J. P. Barry, G. F. W. Clapp, Miss S. Daniels, J. E. Evans, J. O. Friend, C. H. Jarvis, J. S. Job, A. H. Norton, P. K. O'Shaughnessy, H. L. Rigden, S. M. Ross, Miss E. E. Smith, F. J. Smith, R. C. A. Sutherland and A. C. Wall, who have passed the Intermediate B.Sc. examination of London University.

Bishop Shield Competition.—The 1949–50 competition for the Bishop Shield ended with the Air Ministry Annual Sports held at the Polytechnic Stadium, Chiswick, on Wednesday, August 30. The Meteorological Office retained the Shield with a record total of 125 points and also won the Jones Memorial Cup for scoring more points at the Sports than any other division.

One of the most pleasing features of the success of the Office on Sports Day was that so many individuals contributed to it. Nearly one third of the competitors represented the Office and they gained points in all but a few events. For the first time in the competition our team won the tug-of-war, just beating the Directorate of Accounts' side in the final after a long and exhausting contest. In the relay races our ladies' team gained a great victory and the men's team ran well to come in second.

The close of one competition for the Bishop Shield is the signal for the next year's competition to begin and two days after the athletic sports our swimmers gave us a good start for 1950–51. We thank and congratulate all who have done so well in the past, and ask them and other enthusiasts to put forward their best efforts for the coming season and thus ensure a " hat-trick " for the Office in the competition for the Shield.

Retirement—Mr. H. E. Carter, who retired on August 31, 1950, within a few days of his 64th birthday, joined the Meteorological Office in October 1901 when it was housed at 63 Victoria Street. In 1907 he transferred to the British Rainfall Organization under Dr. H. R. Mill and after service in the first world war rejoined the Office, which by that time had taken over the British Rainfall Organization. After service at Lympne and in the Middle East, Mr. Carter was posted in 1936 to the Branch Office at Edinburgh, and in 1946 returned to work on British Rainfall in the British Climatology Branch at Harrow. His chief interest has been rainfall and his keenness for accuracy and gift for spotting errors will long be remembered by those who have worked with him. Good wishes for a long, active and pleasant retirement go with him.

Staff losses.—Four members of the staff of the Meteorological Office were recently transferred to posts in the Executive Class in the Air Ministry. They are: Miss A. W. C. Fitch, who had been in the Office since 1917, the last ten years of which were spent in charge of a section of the Marine Branch; Mr. W. Peniston-Bird, who joined the Office in 1921, and had been in charge of the office at Felixstowe for three years before his transfer; Mr. G. R. Read and Mr. L. Campbell, who had served in the Office since 1934 and 1938 respectively.

We wish these officers every success in their new sphere of work.

The Meteorological Office in Iraq is losing the valuable services of Mr. E. Haren Cohen, Senior Observer. Mr. Cohen first joined the Meteorological Service of Iraq in 1928 while it was under the control of the Royal Air Force. When the service was transferred in 1931 to the Meteorological Office he remained to train locally entered observers to take over the work from airmen. His resignation now is due solely to the necessity for the transfer of his family to Israel.

To the many officers who have served in Iraq since 1928, Mr. Cohen's loyalty, careful work and experience in local matters were of great value and they will wish him well in his new life. A letter of farewell has been received from Mr. Cohen, in which he asks that his good wishes may be conveyed to all staff of the Meteorological Office.

WEATHER OF AUGUST 1950

Mean pressure was above 1020 mb. over the Azores and westward of the Azores nearly to Bermuda, and slightly below 1000 mb. over a small area south of Iceland, centred in about 60°N., 20°W. The mean was below 1005 mb. over part of the Sahara slightly north of the tropics, and below 1010 mb. over southern California and Arizona. Pressure was below the normal for August from the southern shore of the Baltic southwards to the Sahara, over western Europe, the Azores, Iceland, and the Atlantic between southern Greenland and the Azores. The deficit was rather more than 10 mb. southward of Iceland between about latitudes 54°N. and 60°N., but was generally small. Pressure was above normal from the Baltic and the extreme north-west of Russia north-westwards to northern Greenland and Spitsbergen, the excess being about 6 mb. in Finland. Over North America deviations from the normal were small.

In the British Isles the weather of August was generally unsettled and wet on the whole, with frequent thunderstorms. It was very wet in western districts of England and Wales, particularly in the south-west. There were no really hot days, the warmest occurring from about the 4th to the 8th and the 20th to the 22nd, but minimum temperatures were often high. It was sunny in the north and east of Scotland,

During the opening days of the month a shallow depression off the west of Scotland moved east to Denmark causing showers and rather widespread thunderstorms, though there were long bright periods in many places. On the 4th a new depression south-west of Iceland moved slowly east-north-east and associated troughs moved north-east giving rain in the west and north on the 4th and 5th and slight local rain on the 6th. Meanwhile a small anticyclone over north-west France moved north-east and became absorbed in a large anticyclone centred over north Russia. Temperature rose and the period 4th to 8th was warm ; day temperature reached 81°F. in London and 80°F. at Mildenhall on the 6th, 80°F. at London Airport on the 7th and 80°F. at Mildenhall on the 8th. On the 7th and 8th a depression moved from mid Atlantic north-east to westward of Scotland and then turned north, while troughs of low pressure crossed the British Isles giving thunderstorms in eastern districts on the 7th and heavy rain in some parts on the 8th (2·16 in. at Filindre, near Cowbridge, Glamorgan). On the 11th and 12th small secondary disturbances to a depression south of Iceland moved north-east across the country causing rain in the north and west on the 11th and more general rain on the 12th (3·27 in. at Blaenau Festiniog, Merioneth, and 2·11 in. at Rhondda Water Works, Glamorgan on the 11th). On the 14th a wedge moved east over England and mainly fair weather prevailed in the south and east but more rain occurred in the west and north. On the 15th a depression developed off north-west Scotland and moved north and later turned west. Meanwhile associated secondary depressions or troughs moved irregularly north over the British Isles ; rain, heavy in places, fell on the 15th (2·70 in. at Blaenau Festiniog) and in the following days rather cool weather prevailed, with frequent showers and fairly widespread thunderstorms. By the 20th pressure was high over Germany and low north-westward of Ireland, while a new depression developed in mid Atlantic and moved quickly east to the west of Ireland where it remained almost stationary until the 23rd. Temperature rose again reaching 78°F. at London Airport and Guernsey on the 21st and 80°F. at Mildenhall and London Airport on the 22nd. Shallow troughs moved over the British Isles giving heavy rain locally particularly in the south-west and in Lancashire on the 20th (1·90 in. at Wigan Water Works, Worthington, Lancashire), and local thunder in eastern districts on the 21st. On the 22nd and 23rd cold fronts moving east across the country caused showers and widespread thunderstorms, with heavy rain locally. Thereafter, on the 24th a shallow secondary depression off our south-west coasts moved north-north-east and on the 25th and 26th another shallow secondary off south-west Ireland moved north ; rain and thunderstorms occurred, the latter being widespread on the 24th, but there were also sunny periods. Again, on the 27th and 28th, a trough of low pressure west of Ireland moved slowly south-east giving showers, rather widespread thunderstorms, and heavy local rain. Subsequently troughs to a shallow disturbance off north-west Ireland moving across England caused further thundery rains, which were heavy locally on the 30th, 2·09 in. being registered at Guernsey. Thunderstorms in south-east England on the 31st were associated with a shallow depression over northern France.

The general character of the weather is shown by the following provisional figures :—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Per-centage of average	No. of days difference from average	Per-centage of average
	°F.	°F.	°F.	%		%
England and Wales ..	83	40	+0·3	147	+3	99
Scotland	74	31	+1·0	115	+2	116
Northern Ireland ..	72	39	−0·2	135	+5	95

RAINFALL OF AUGUST 1950
Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square	2·56	116	*Glam.*	Cardiff, Penylan	8·68	205
Kent	Folkestone, Cherry Gdn.	2·63	110	*Pemb.*	St. Ann's Head	6·59	198
,,	Edenbridge, Falconhurst	3·38	129	*Card.*	Aberystwyth	8·21	214
Sussex	Compton, Compton Ho.	3·92	127	*Radnor*	Tyrmynydd	8·17	152
,,	Worthing, Beach Ho. Pk.	2·43	108	*Mont.*	Lake Vyrnwy	8·48	159
Hants	Ventnor, Roy. Nat. Hos.	2·80	141	*Mer.*	Blaenau Festiniog	20·00	179
,,	Bournemouth	2·00	79	*Carn.*	Llandudno	3·97	141
,,	Sherborne St. John	3·82	158	*Angl.*	Llanerchymedd	6·34	175
Herts.	Royston, Therfield Rec.	3·78	147	*I. Man*	Douglas, Borough Cem.	7·21	189
Bucks.	Slough, Upton	3·43	158	*Wigtown*	Port William, Monreith	6·23	162
Oxford	Oxford, Radcliffe	3·05	134	*Dumf.*	Dumfries, Crichton R.I.	6·32	156
N'hant.	Wellingboro', Swanspool	1·70	71	,,	Eskdalemuir Obsy.	8·12	160
Essex	Shoeburyness	1·63	92	*Roxb.*	Kelso, Floors	3·04	103
,,	Dovercourt	1·72	96	*Peebles*	Stobo Castle	3·75	105
Suffolk	Lowestoft Sec. School	1·58	72	*Berwick*	Marchmont House	2·72	82
,,	Bury St. Ed., Westley H.	1·72	66	*E. Loth.*	North Berwick Res.	2·23	71
Norfolk	Sandringham Ho. Gdns.	4·64	172	*Midl'n*	Edinburgh, Blackf'd. H.	2·32	72
Wilts	Bishops Cannings	2·66	86	*Lanark*	Hamilton W. W., T'nhill	5·29	155
Dorset	Creech Grange	3·50	122	*Ayr*	Colmonell, Knockdolian	5·01	125
,,	Beaminster, East St.	5·54	177	,,	Glen Afton, Ayr San.	5·37	99
Devon	Teignmouth, Den Gdns.	3·29	146	*Bute*	Rothsay, Ardencraig	5·61	115
,,	Cullompton	5·74	188	*Argyll*	L. Sunart, Glenborrodale	..	..
,,	Ilfracombe	7·89	220	,,	Poltalloch	6·82	139
,,	Okehampton, Uplands	7·62	180	,,	Inveraray Castle	7·63	116
Cornwall	Bude, School House	6·13	217	,,	Islay, Eallabus	5·95	136
,,	Penzance, Morrab Gdns.	6·71	212	,,	Tiree	4·88	116
,,	St. Austell	7·26	201	*Kinross*	Loch Leven Sluice	4·19	109
,,	Scilly, Tresco Abbey	4·32	157	*Fife*	Leuchars Airfield	2·45	80
Glos.	Cirencester	4·75	158	*Perth*	Loch Dhu	9·24	137
Salop.	Church Stretton	3·58	107	,,	Crieff, Strathearn Hyd.	7·03	167
,,	Cheswardine Hall	7·00	211	,,	Pitlochry, Fincastle	5·11	144
Worcs.	Malvern, Free Library	3·62	125	*Angus*	Montrose, Sunnyside	3·13	112
Warwick	Birmingham, Edgbaston	3·21	118	*Aberd.*	Braemar	3·58	105
Leics.	Thornton Reservoir	2·59	93	,,	Dyce, Craibstone	3·18	105
Lincs.	Boston, Skirbeck	1·82	76	,,	Fyvie Castle	2·60	82
,,	Skegness, Marine Gdns.	2·78	114	*Moray*	Gordon Castle	1·92	61
Notts.	Mansfield, Carr Bank	3·71	133	*Nairn*	Nairn, Achareidh	1·98	81
Derby	Buxton, Terrace Slopes	4·80	110	*Inverness*	Loch Ness, Garthbeg	3·45	106
Ches.	Bidston Observatory	5·57	181	,,	Glenquoich	8·53	104
Lancs.	Manchester, Whit. Park	..	..	,,	Fort William, Teviot	7·67	123
,,	Stonyhurst College	8·90	176	,,	Skye, Duntuilm	5·66	127
,,	Squires Gate	6·60	193	*R. and C.*	Tain, Tarlogie House	2·20	81
Yorks.	Wakefield, Clarence Pk.	3·71	143	,,	Inverbroom, Glackour	4·54	109
,,	Hull, Pearson Park	4·48	154	,,	Applecross Gardens	6·38	135
,,	Felixkirk, Mt. St. John	4·50	158	,,	Achnashellach	6·11	110
,,	York Museum	4·86	193	,,	Stornoway Airfield	3·54	94
,,	Scarborough	3·82	138	*Suth.*	Loch More, Achfary	6·32	108
,,	Middlesbrough	4·66	170	*Caith.*	Wick Airfield	3·44	125
,,	Baldersdale, Hury Res.	5·86	168	*Shetland*	Lerwick Observatory	4·37	145
Norl'd.	Newcastle, Leazes Pk.	5·32	189	*Ferm.*	Crom Castle	5·94	143
,,	Bellingham, High Green	4·32	122	*Armagh*	Armagh Observatory	5·30	146
,,	Lilburn Tower Gdns.	2·62	93	*Down*	Seaforde	5·68	151
Cumb.	Geltsdale	6·82	165	*Antrim*	Aldergrove Airfield	4·02	112
,,	Keswick, High Hill	8·06	154	,,	Ballymena, Harryville	6·37	149
,,	Ravenglass, The Grove	6·28	138	*L'derry*	Garvagh, Moneydig	5·28	135
Mon.	Abergavenny, Larchfield	5·50	185	,,	Londonderry, Creggan	4·61	99
Glam.	Ystalyfera, Wern House	13·46	218	*Tyrone*	Omagh, Edenfel	6·16	144

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LERWICK OBSERVATORY

By W. G. HARPER, M.Sc.

With an historical introduction by Dr. A. H. R. Goldie

Historical.—The Observatory was opened in 1921 by the Meteorological Office, primarily as a magnetic observatory. On Dr. Crichton Mitchell, at that time Superintendent of the Office in Edinburgh, and Mr. J. Crichton, the first officer in charge at Lerwick, fell the chief burden of the initial set-up, at a time when the shortages arising from the 1914–18 war had not been overcome and the difficulties associated with economy cuts were just beginning.

To explain why it had for some years been regarded as specially important to have a magnetic observatory in Shetland, one must go back some way in time.

Half a century ago it was known that the earth's magnetic field was undergoing a gradual change (secular change), also that there were regular diurnal variations of the components of magnetic force varying with the seasons, and further that there was at times irregular disturbance—magnetic storms. An important practical use for continuous magnetic records lay therefore in the reduction of the results of magnetic surveys to a common base or epoch and this of course is still the case. At the time Rücker and Thorpe were engaged on their great work[1]* on the magnetic survey of the British Isles for the epoch 1891; it was, however, supposed that both the regular diurnal variation and the disturbance vectors could be regarded as practically invariable in amplitude within the region of the British Isles. As the late Dr. Chree[2] said " The hypothetical nature of these conclusions was clearly recognized by Rücker and Thorpe but they believed them sufficiently good approximations to the truth to justify their referring all their field observations to a single base station, Kew Observatory, in the south of England . . . "

As soon, however, as records became available from Eskdalemuir, it was obvious that natural magnetic disturbance was considerably larger than at Kew, and the desirability of records from a British station a good deal to the north of Eskdalemuir was gradually recognized.

Later it was found that at times of magnetic storms, the displacements of magnetic force from its normal value were on the average actually about twice as great at Eskdalemuir as at Abinger, the magnetic station in Surrey which replaced Greenwich, although Eskdalemuir is less than 300 miles north of Abinger. And in turn the displacements at Lerwick, 330 miles further north, were found to be usually more than twice as great as those at Eskdalemuir. Thus not only were three magnetic observatories needed to permit exact survey work in the British Isles, but it was soon appreciated that the data of three observatories, roughly on a north-south line, offered a special opportunity for research on the position and pattern of the electric-current systems associated with magnetic disturbance. And of these observatories it seemed that Lerwick had a special value as being apparently near the latitude where the electric-current systems reach their greatest concentration.

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* The index numbers refer to the list of references on p. 314.

When adequate recordings had accumulated, it was possible to compute that the principal concentration of electric current lay as a rule several hundred miles northward of Lerwick, but that it sometimes came actually a little to the southward of Lerwick, just as the aurora was sometimes seen to come southward of the zenith there. The height of this current was found to average about 100 Km. in winter, but at other times of the year it appeared to be more diffuse and centred at a greater height—some 300 Km. The magnitude of the current ranges up to 300,000 amp. or more in very great storms. In a modest storm in winter or in a magnetically quiet year it may be only some 50,000 amp.

Buildings and site.—Surrounded by peaty heather-covered moorland with scattered lochs, the Observatory stands on a ridge of high ground about 280 ft. above sea level. The buildings have a very open exposure, obtaining slight shelter from only one direction, where Shurton Hill rises a further 300 ft. about a mile away to the west-north-west. Lerwick, the county town and chief port of Shetland, 2½ miles away by road, has a frequent boat service direct to Aberdeen.

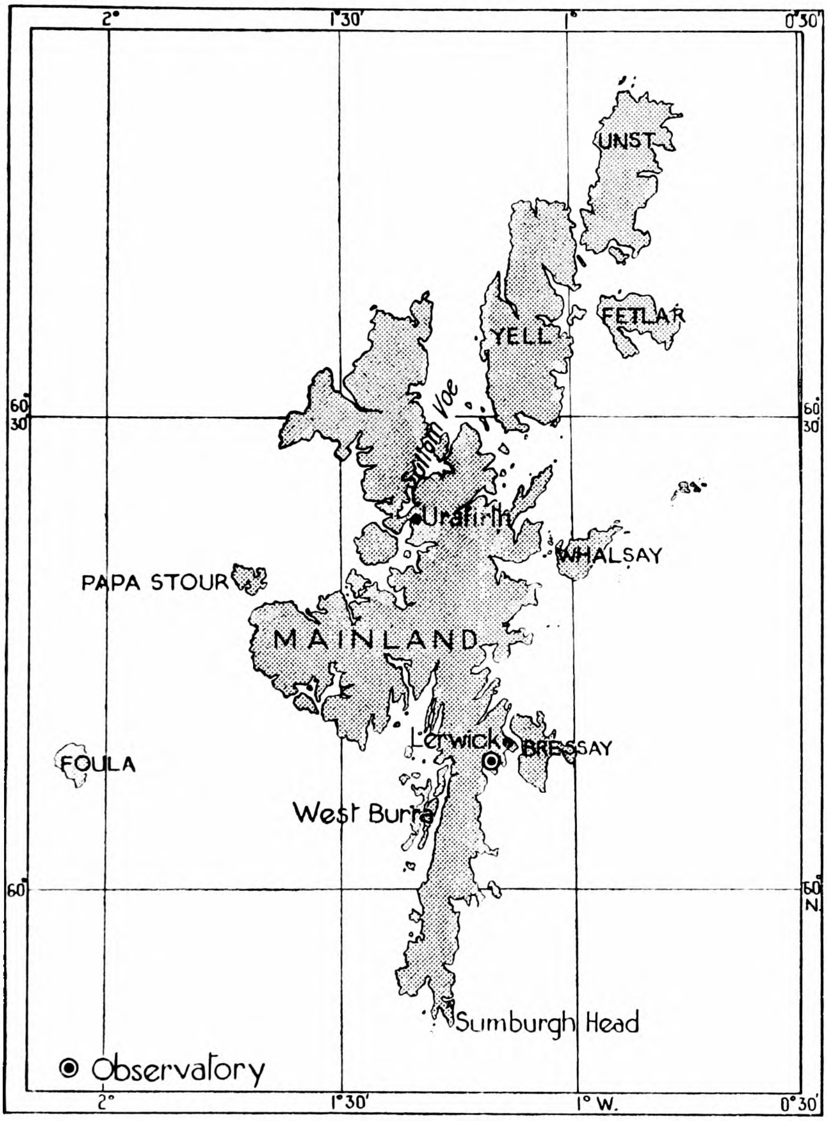
The main buildings, originally a wireless station built in 1913 by the Admiralty, became the Observatory offices and also house the staff.

Magnetic equipment.—The concrete hut built for the standard recording magnetographs lies about 300 yd. south-east of the main Observatory buildings on the open hill-side. It has walls nearly two ft. thick, designed to keep temperature variations to a minimum. Nearby wooden huts house the auxiliary recording magnetographs and the absolute magnetometers.

The main recording magnetographs are a La Cour standard set, originally used by the British Polar Year expedition at Fort Rae in 1932–33. The set has three components for horizontal force *H*, declination *D*, and vertical force *V*, arranged to record on a single drum of photographic paper 30 cm. wide, with a time scale of 15 mm./hr. These instruments were specially designed at Copenhagen for recording the wide ranges in the magnetic elements which occur in polar regions. An ingenious series of 18 reflecting prisms is used to multiply the range of record. The prisms give a series of reflected traces, adjusted so that, as one light spot moves off the photographic paper in a magnetic disturbance, the next reflected spot moves on to continue the record.

An older set of magnetographs, which had been in use as standard recorders until 1934, is installed in a separate hut as an auxiliary set. They also record photographically, and comprise a Munro *H*, a Munro *D* and a Watson quartz-fibre *V* which had been made specially for Lerwick some years earlier. The Munro magnetographs had been in use at Falmouth until 1912.

Installed in the concrete hut, in addition to the La Cour standard instruments, is a La Cour quick-run set, which also had been in use at Fort Rae. With a time-scale of 3 mm./min. (12 times as open as the standard traces) these records are used for timing sudden disturbances accurately. Some of these disturbances, associated with the onset of magnetic storms, are recorded by magnetographs all over the world. The general principles of the quick-run magnetographs are similar to those of the La Cour standard set, but 50 reflecting prisms are employed, each requiring separate adjustment.


2°
1°30′
1°
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UNST
YELL
FETLAR
Yell Sound
Voe
Urafirth
WHALSAY
PAPA STOUR
MAINLAND
FOULA
Lerwick
BRESSAY
West Burra
Sumburgh Head
Observatory
60 30
60
60 N.
1° W.

MAP SHOWING THE POSITION OF LERWICK OBSERVATORY IN SHETLAND

Absolute magnetic observations are made three times weekly, using a Kew unifilar magnetometer for *D*, a Schuster-Smith coil magnetometer for *H*, and a Copenhagen balance magnetometer for *V*. In accordance with modern practice the two latter instruments are checked periodically against other observatories, using as travelling standards a quartz horizontal magnetometer and zero balance magnetometer, also recently developed at Copenhagen.

H and *V* can be measured almost to 1γ with these instruments ($1\gamma=0.00001$ c.g.s. units of magnetic intensity). As normal values for *H* and *V* at Lerwick are $14{,}350\gamma$ and $47{,}000\gamma$, the refinement of these magnetometers can be appreciated. Hourly values are measured from the magnetograms, and indices of the degree of magnetic disturbance (*K* indices and *C* figures) are evaluated in accordance with international arrangements.

Auroral work.—The detailed study of auroræ was one of the primary purposes for establishing the Observatory, and ever since its opening a regular auroral watch has been maintained. It is kept normally from dusk until 10 p.m., and is continued if the aurora is still active. Few auroral displays commence after 10 p.m., but if one is seen, the trained observer is called out. In summer the light evenings make observation of all but intense auroral activity impossible. In spite of the fact that, for almost half the time in Shetland, observation is limited by overcast cloud, auroræ are reported on between 40 and 80 nights each year.

Work in auroral photography has been done intermittently to supplement the visual records, while during the Polar Year 1932–33 simultaneous auroral photographs were taken, whenever possible, at the Observatory and at Urafirth about 26 miles to the north. Urafirth was selected because the line between it and Lerwick is roughly perpendicular to the most frequently occurring direction of auroral arcs. This work was limited even more severely by cloud conditions.

Atmospheric electricity.—Records of the potential gradient of atmospheric electricity have been maintained continuously since 1926 with a Benndorf electrograph. The insulated collector of the electrograph is a copper rod tipped with polonium, which projects from the wall of the main office building almost five metres above the ground.

The electrograph, which has a scale value of about 32 v./mm., has a range of recording of ±2,000 v./m., yet these values are frequently exceeded when precipitation is falling on the collector. The record consists of a series of dots made once a minute on a recording drum. Insulation and scale tests of the system are made daily with a Wulf electrometer.

Hourly values measured from this record are reduced to absolute values by comparison against observations made with the Wulf electrometer. A stretched wire and polonium collector a metre above level ground clear of all Observatory buildings, are used for these measurements.

Radio-sonde.—The work of the Observatory, and the number of its staff, increased greatly with the introduction of radio-sonde work in 1940, and Lerwick has become a vital part of the network of land stations and ocean weather ships which make regular upper air observations.

Upper air temperatures and humidities are measured well into the stratosphere with the Meteorological Office pattern radio-sonde, while radar now is used for the measurement of upper winds. With light or moderate upper winds, reports are usually limited only by the bursting of the balloon, but with strong upper winds, frequently by the limit of range of the radar set.

From 1942 until 1946 radio direction-finding methods were used for the measurement of upper winds.[3] The Observatory was the launching site for the radio-sonde, while D/F sites were located at Ness of Sound, 1¼ miles east-south-east, at Walls, 16 miles west-north-west, and at Brough, 24 miles north of the Observatory. Necessarily chosen for their freedom from electrical interference, these sites were inevitably in isolated localities, and at times great difficulty was experienced in supplying and manning them. On one occasion in 1945, when the detachment of two men at Walls was cut off completely by snow-drifts and several attempts at relief had failed, rations were dropped by air. The introduction in 1946 of radar methods for the measurement of upper winds made the D/F sites unnecessary and disposed of these problems.

Since 1943 a full programme, with radio-sonde and D/F or, later, radar-wind observations every six hours, has been maintained. Despite the very high frequency of gales in the winter months, no radar-wind observations were missed in 1948 and only one radio-sonde observation. This is no small tribute to the equipment provided and to the keenness and efficiency of the staff.

Meteorological records.—The Observatory is also a fully equipped climatological station, with a Dines pressure-tube anemometer, a float barograph and a microbarograph, in addition to the more usual equipment of an observing station. Hourly weather observations are made and dispatched to the Central Forecasting Office at Dunstable by teleprinter.

A night-sky camera, which records the periods during which the pole star is unobscured by clouds, is operated for nine months of the year. In summer the nights are too light to justify its use.

Other geophysical work.—The Observatory is intended to facilitate any geophysical research work for which its position renders it specially suitable.

It may be of interest to record that it was associated with some of the early work in radio direction-finding, and in the location of atmospherics (now commonly known as " sferics "). Direction-finding equipment was in operation in 1923, while atmospherics were recorded for the Department of Scientific and Industrial Research from 1924 until 1929. The three stations employed in this work were the Radio Research Station at Ditton Park near Slough in Buckinghamshire, Lerwick 600 miles to the north and Aboukir in Egypt, 2,000 miles to the south-east.

Between 1921 and 1928 work was done on the luminosity of the night sky, and in auroral spectroscopic photography. The work was initiated by the late Lord Rayleigh, who himself visited the Observatory soon after its opening, bringing a set of three instruments with him. Despite a by no means smooth passage across the Pentland Firth, his energy and enthusiasm were such that by the evening of his arrival two instruments had been set up and were in operation.

Work also has been done and will again be done on ozone. An ozone spectrograph was in use in 1926–27, while a much improved instrument designed by Dr. G. M. B. Dobson, an ozone photo-electric spectrophotometer, was operated from 1940 to 1943.

Finally, a smoke pollution apparatus is maintained for the Director of Fuel Research. It need hardly be said that the intention here is to get measurements of relatively uncontaminated air. In the two years in which this record has been available less pollution has been recorded at the Observatory than at any other reporting station in Great Britain.

Life at the observatory.—Actual living conditions are greatly improved from what they were originally. Then lighting was by oil lamps, while water was pumped from a nearby loch by wind pump, which was liable to give trouble. The domestic arrangements in the houses were " austere ". The present water supply comes from Lerwick Waterworks, while all lighting is by electricity.

As elsewhere, living accommodation is a great difficulty, but a limited number of married quarters are available at the Observatory, and some of the houses are run as a hostel for the single staff.

To anyone interested in ornithology or in the " gentle art " of fishing, Shetland can be fascinating. It has loch and sea trout in large numbers, and a great variety of sea birds and waders. The island of Noss, a few miles beyond Lerwick, is maintained as a bird sanctuary, its nesting cliffs rising a sheer 592 ft. from the sea.

The length of day at midsummer is $18\frac{3}{4}$ hr., so that it is quite light throughout the night. The midwinter day is $5\frac{1}{2}$ hr. and the sun's altitude at noon $6\frac{3}{4}°$ as compared with $16\frac{1}{2}°$ for the extreme south of England. A cloudy winter day in Shetland therefore affords very poor light. The wind averages over 20 m.p.h. in winter as compared with 8 m.p.h. at Kew. It sometimes averages 30 m.p.h. in a month and may blow at over gale force with scarcely a let-up for days on end. Some people find these winter conditions of wind and poor daylight trying.

The climate however is comparatively mild, and it is difficult to realize that Shetland lies as far north as Cape Farewell in Greenland. Yet it is its magnetic latitude and its position close to the track of many Atlantic depressions, that make the geophysical and meteorological records of the Observatory of such value.

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VARIATION OF UPPER AIR TEMPERATURE WITH SEASON AND LATITUDE

The collection and summarizing of upper air data by the Upper Air Climatology Section of the Meteorological Office for the preparation of charts of average temperature at different levels over the world has brought to light some interesting facts. A brief note of some of them may be of value in advance of the main publication.

Of the ten stations referred to in this note, seven are under the direct control of the British Meteorological Office; of the remaining three, Langenhagen in the British zone of Germany and Nairobi in British East Africa both use British instruments and send their data to the section dealing with upper air climatology at Harrow. The information for Jan Mayen is from data made available to the Meteorological Office by the courtesy of Dr. Sverre Petterssen and the Royal Norwegian Air Force. Particulars of the co-ordinates of the stations, periods, etc., are given in Table I.

TABLE I—UPPER AIR STATIONS CONTRIBUTING DATA

Station	Lat.	Long.	Period	Number of observations January 700 mb.	Number of observations January 100 mb.	Number of observations July 700 mb.	Number of observations July 100 mb.	Times of observation
								G.M.T.
Jan Mayen	71°01'N.	8°26'W.	July 1944–July 1945	62	40	123	81	1100, 2300
Lerwick	60°08'N.	1°11'W.	July 1945–Jan. 1950	618	382	620	401	0000, 0600, 1200, 1800
Langenhagen	52°28'N.	9°42'E.	July 1947–July 1949	186	61	247	178	0200, 0800, 1400, 2000
Larkhill	51°11'N.	1°48'W.	July 1945–July 1949	496	272	620	419	0000, 0600, 1200, 1800
Gibraltar (North Front)	36°09'N.	5°21'W.	July 1946–July 1949*	195	67	243	140	0430, 1500
Malta (Qrendi)	35°50'N.	14°27'E.	July 1946–July 1949	149	85	182	151	0200, 1500
Habbaniya	33°22'N.	43°34'E.	July 1946–July 1949†	284	81	322	114	1700 mainly
Bahrein	26°14'N.	50°35'E.	July 1947–July 1949	62	48	88	67	1500 mainly
Aden	12°50'N.	45°01'E.	July 1948–Jan. 1950	69	55	42	31	1400 mainly
Nairobi	1°17'S.	36°50'E.	June 1947–Dec. 1949	50	34	84	77	0600

*Also 1945–46 at 0800 and 1700 for 700 and 500 mb. †1943–49 at 700 and 500 mb.

TABLE II—AVERAGE TEMPERATURE OF STANDARD ISOBARIC SURFACES AND THE RANGE WITHIN WHICH 95 PER CENT. OF THE OBSERVATIONS LIE

	Average		95 per cent. range		Average		95 per cent. range	
	Jan.	July	Jan.	July	Jan.	July	Jan.	July
mb.	°A.	°A.	°A.	°A.	°A.	°A.	°A.	°A.
	JAN MAYEN				LERWICK			
100	204	230	11	9	215	227	18	12
150	208	229	13	11	217	226	22	15
200	210	227	21	17	216	225	23	20
300	214	228	14	14	222	230	15	13
500	235	253	20	16	245	256	19	14
700	251	267	22	16	262	272	15	12
	LANGENHAGEN				LARKHILL			
100	218	223	15	17	216	221	19	13
150	218	223	20	20	217	222	21	17
200	217	223	20	19	215	221	22	18
300	224	232	12	14	225	233	13	13
500	248	259	17	13	249	259	20	13
700	264	274	18	14	265	274	18	14
	GIBRALTAR				MALTA			
100	213	209	20	11	213	208	12	13
150	215	213	26	13	216	215	18	13
200	216	221	19	13	217	224	21	12
300	228	237	12	10	227	238	9	13
500	253	263	17	9	253	264	14	10
700	270	284	19	7	269	281	15	11
	HABBANIYA				BAHREIN			
100	210	202	14	15	204	199	13	13
150	215	214	13	16	212	213	15	15
200	218	227	18	14	220	227	15	14
300	227	247	11	11	233	248	16	12
500	253	270	12	12	258	269	14	13
700	269	287	12	9	275	290	13	7
	ADEN				NAIROBI			
100	195	196	11	(13)	196	200	(10)	13
150	207	207	8	(11)	208	208	14	13
200	220	221	8	9	221	219	10	9
300	241	243	7	7	242	241	6	8
500	267	267	5	7	267	267	6	6
700	283	289	6	5	283	281	6	7

Figures in brackets indicate less than 40 observations.

Table II gives the average temperature in January and July of the isobaric surfaces of 700, 500, 300, 200, 150 and 100 mb. together with the ranges within which 95 per cent. of the individual observations lie. The averages are plotted in Fig. 1.

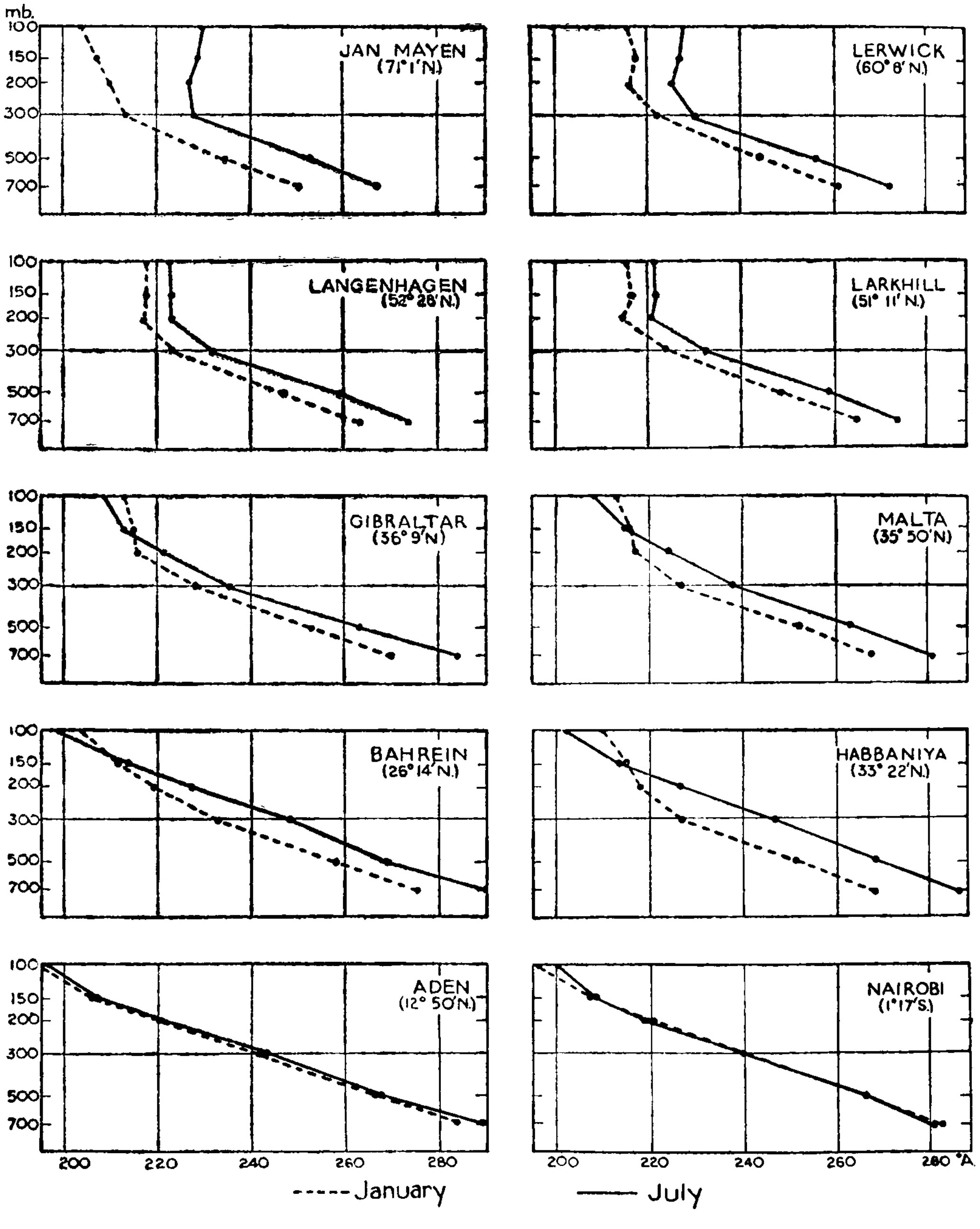

FIG. 1—VARIATION OF AVERAGE TEMPERATURE WITH HEIGHT

The most striking feature is the seasonal variation of temperature in the stratosphere. In the far north at Jan Mayen the average difference of temperature between January and July becomes greater with increasing height —at 300 mb. it is 14°A., at 100 mb. 26°A. The increase appears to be due to the continued falling off of temperature above 300 mb. in January whereas in July the stratosphere is nearly isothermal. A similar increase is shown in the war-time ascents at Vadsø in north Norway where the range is 15°A. at 300 mb. and 24°A.

at 96 mb., but there it is associated with an increase of stratospheric temperature with height in July rather than with a decrease in January. A similar though less well marked increase is shown in the diagram for Lerwick, some 10° farther south, but not at Larkhill or Langenhagen where the range in the stratosphere is less than in the troposphere.

South of about latitude 40°N. the seasonal variation of temperature in the stratosphere is the reverse of that at the surface, July showing lower temperatures than January; 4° or 5°A. lower at Malta and Gibraltar and 8°A. at Habbaniya. This change in regime is associated with a well marked seasonal variation in the height of the tropopause, January tropopauses being appreciably lower than those in July.* Farther south, in equatorial regions, the seasonal range in the temperature of the stratosphere is small, and such evidence as there is indicates that January is slightly cooler than July.

Approximate values of the range of temperature within which 95 per cent. of the observations lie are also given in Table II. There is a good deal of irregularity in the values, part of which may be due to uncertainty in making the estimates, but the most marked feature is the much greater range, particularly in the higher latitudes, at 200 mb. than at 300 mb. At stations north of 30°N. in both seasons, 200 mb. is the level at which the range is greatest, except at Gibraltar in January where the maximum is at 150 mb.—this is much less conspicuous if the 80 per cent. range is used rather than the 95 per cent.

The change of temperature with latitude along isobaric surfaces in the troposphere shows the expected decrease with increase of latitude, greater in winter than in summer. The large difference between Malta and Habbaniya in July is a reminder, however, that latitude is not by any means the only factor of importance.

The change of temperature with latitude at higher levels is of great interest. At 200 mb. the extreme range in both months is only about 10°A., from 210° to 221°A. in January and from 219° to 227°A. (in the reverse direction) in July. That the level at which the day-to-day variations are greatest should be the same as that at which the variation with latitude is least is remarkable. It suggests that the large day-to-day changes are due to vertical rather than to longitudinal motion—but it must be remembered that longitudinal motion does not necessarily take place along an isobaric surface.

At 150 and 100 mb. average temperature is fairly uniform in January between 40°N. and 60°N. but decreases thence both towards the pole and the equator, the latter being the region of greater cold. In July on the other hand temperature falls southwards from 70°N. to about 10°N. the rate of fall being greatest in middle latitudes. In July, Aden is appreciably colder than Nairobi at 100 mb.

These results refer to stations in Europe, the Middle East and Africa ; a comparison with similar data for the American continent would be of considerable interest.

Frequencies of tropopause pressures.—Table III gives the frequency, expressed as a percentage, with which pressure at the tropopause lies within successive 20-mb. ranges. The column 420 refers to the 20-mb. range 410–429mb.

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* After this note was written, average temperatures for stations in New Zealand between 29°S. and 45°S. were received from the Director of the New Zealand Meteorological Service. They show similar characteristics, i.e. lower stratospheric temperatures and higher tropopause in summer (January) than in winter (July).

TABLE III—PERCENTAGE FREQUENCIES

millibars

	≥430	420	400	380	360	340	320	300	280	260	240
					percentage frequency						
RADIO-SONDE STATIONS											
Lerwick											
Dec.—Feb.	1	1	2	3	2	3	4	10	11	11	13
June—Aug.	...	...	<0·5	0·5	1	2	4	7	11	17	18
Larkhill											
Jan.	<0·5	<0·5	1	2	2	3	3	6	7	12	12
July	<0·5	...	...	<0·5	1	1	1	4	5	10	15
Gibraltar											
Dec.—Feb.	...	<0·5	<0·5	1	1	1	1	5	5	10	15
June—Aug.	...	...	...	...	...	...	...	...	1	1	2
Malta											
Dec.—Feb.	...	<0·5	<0·5	1	<0·5	2	4	3	6	13	16
June—Aug.	...	...	...	...	...	...	<0·5	<0·5	1	2	5
Nicosia											
Dec.—Feb.	<0·5	<0·5	1	2	3	1	4	6	11	11	18
June—Aug.	...	...	...	...	...	...	1	...	1	1	3
Habbaniya											
Dec.—Feb.	...	...	...	...	1	...	1	4	5	8	14
June—Aug.	...	...	...	...	...	...	...	...	<0·5	...	...
Benina											
Dec.—Feb.	...	...	1	1	2	1	3	1	4	11	15
June—Aug.	...	...	...	...	...	...	...	1	1	4	3
Bahrein											
Dec.—Feb.	...	...	...	...	...	...	...	...	...	...	...
June—Aug.	...	...	...	...	...	...	...	...	...	...	...
Aden											
Dec.—Feb.	...	...	...	...	...	...	...	...	...	...	...
June—Aug.	...	...	...	...	...	...	...	...	...	...	...
Nairobi											
Dec.—Feb.	...	...	...	...	...	...	...	...	...	...	...
June—Aug.	...	...	...	...	...	...	...	...	...	...	...
BALLON-SONDE STATIONS											
England											
Dec.—Feb.	...	1	1	...	2	4	4	8	3	9	22
June—Aug.	...	...	...	...	...	1	4	4	9	8	16
Agra											
Dec.—Feb.	...	...	...	...	...	...	...	...	...	...	1
June—Aug.	...	...	...	...	...	...	...	...	...	...	...
India N. of 20°N.											
Dec.—Feb.	...	...	...	...	...	...	...	...	...	...	2
June—Aug.	...	...	...	...	...	...	...	...	...	...	...
India S. of 20°N.											
Dec.—Feb.	...	...	...	...	...	...	...	...	...	...	...
June—Aug.	...	...	...	...	...	...	...	...	...	...	...

and so on. Values are given for two seasons, December–February and June–August, except at Larkhill where January and July only have been used. The upper part of the table refers to data from radio-sondes and the lower part to ballons-sondes. All the data are from manuscript records in the Meteorological Office, except those for India which were extracted from *Upper Air Data* published by the India Meteorological Department. The frequencies from the radio-sonde observations are plotted in Fig. 2 and from the ballons-sondes in Fig. 3.

In winter the marked difference in the character of the diagrams for stations north and south of 30°N. is very striking. There is, however, some indication that even in that season the tropical regime sometimes penetrates as far north as Habbaniya and may even reach the Mediterranean. The comparatively large number of low tropopauses at Nicosia may be associated with the Cyprus "low", characteristic of the winter months.

OF TROPOPAUSE PRESSURES

	millibars										No. of obs.
	220	200	180	160	140	120	100	80	60	40	
					percentage frequency						
RADIO-SONDE STATIONS											
Lerwick											
Dec.—Feb.	14	13	9	3	<0·5	...	...	...	...	...	351
June—Aug.	20	15	4	1	...	...	...	...	...	...	418
Larkhill											
Jan.	19	18	12	2	1	...	...	...	...	...	476
July	28	21	10	3	1	...	...	...	...	...	580
Gibraltar											
Dec.—Feb.	13	25	16	5	1	<0·5	1	...	...	...	301
June—Aug.	4	12	18	16	18	16	11	1	<0·5	...	366
Malta											
Dec.—Feb.	19	19	11	4	1	1	<0·5	...	...	...	446
June—Aug.	6	11	7	9	14	21	19	5	...	...	422
Nicosia											
Dec.—Feb.	15	16	7	1	1	1	1	1	...	...	324
June—Aug.	4	6	4	2	9	21	36	11	1	...	157
Habbaniya											
Dec.—Feb.	19	20	9	5	2	3	7	2	...	...	425
June—Aug.	...	<0·5	1	<0·5	<0·5	6	32	45	13	1	247
Benina											
Dec.—Feb.	22	20	11	5	3	<0·5	...	<0·5	...	...	322
June—Aug.	...	2	4	4	3	12	44	20	2	...	127
Bahrein											
Dec.—Feb.	...	...	1	2	5	7	39	38	8	...	146
June—Aug.	...	...	...	...	...	4	20	55	19	2	84
Aden											
Dec.—Feb.	...	...	...	...	2	12	40	44	2	...	127
June—Aug.	...	...	...	...	...	9	55	36	...	...	90
Nairobi											
Dec.—Feb.	...	...	...	...	1	9	29	47	14	...	101
June—Aug.	...	...	...	...	4	13	55	24	4	...	114
BALLON-SONDE STATIONS											
England											
Dec.—Feb.	17	16	12	1	...	...	...	...	...	...	139
June—Aug.	21	28	7	1	1	...	...	...	...	...	134
Agra											
Dec.—Feb.	1	3	1	3	5	20	42	23	1	...	151
June—Aug.	...	...	...	1	1	18	61	19	...	...	102
India N. of 20°N.											
Dec.—Feb.	...	...	...	2	7	20	49	18	2	...	55
June—Aug.	...	...	...	...	4	26	56	14	...	...	97
India S. of 20°N.											
Dec.—Feb.	...	...	1	6	12	34	32	14	1	...	132
June—Aug.	...	...	...	...	5	49	35	10	1	...	74

In summer the contrast is less well marked; high tropopauses, with pressure as low as 100 mb., are found not infrequently even in the western Mediterranean and are more frequent than any other type in the eastern (Nicosia). Occasionally, however, the lower tropopauses of middle latitudes are found as far south as 30°N., though from the Mediterranean southwards the tropopause in summer rarely falls below the 300-mb. level.

It is of some interest that at both Nairobi and Aden the frequency of very high tropopauses (pressure less than 90 mb.) is greater from December to February than from June to August.

In June–August the tropopause at Bahrein is usually at a higher level than at Aden or Nairobi; on 76 per cent. of occasions the tropopause pressure is less than 90 mb. compared with 36 per cent. and 28 per cent. respectively at the other two stations.

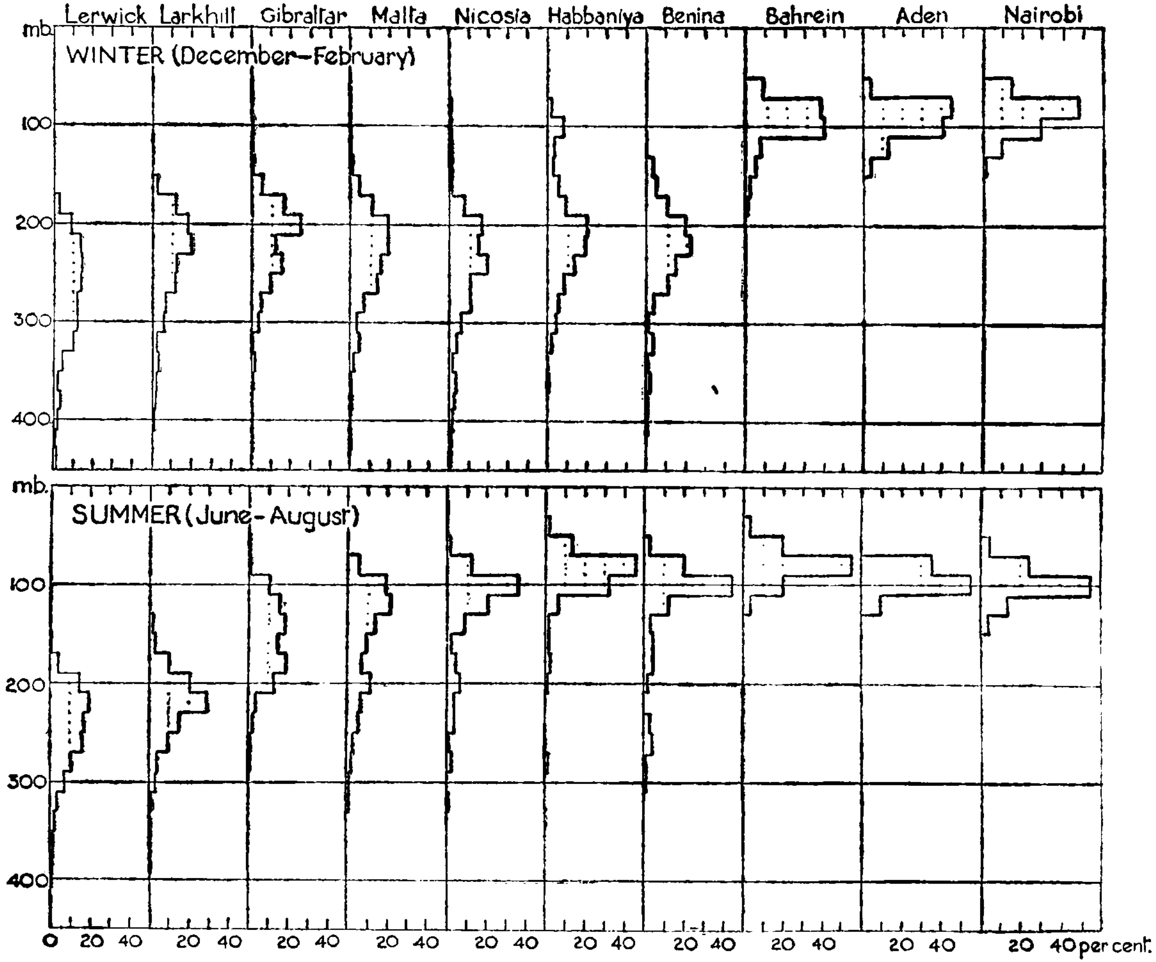

FIG. 2—FREQUENCIES OF TROPOPAUSE PRESSURES

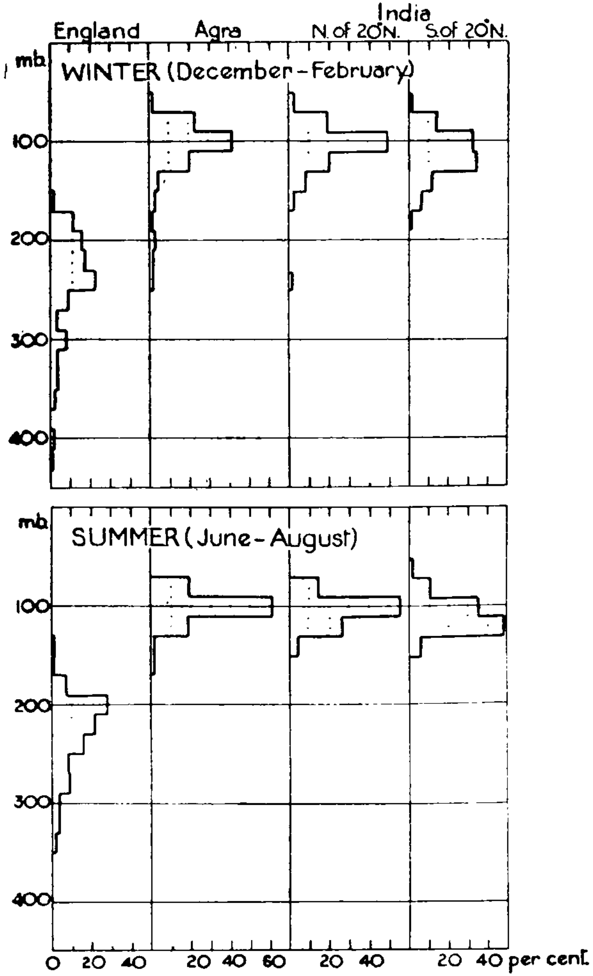

FIG. 3—FREQUENCIES OF TROPOPAUSE PRESSURES OVER ENGLAND AND INDIA

For comparison with the radio-sonde data, frequencies from ballon-sonde data are given for England and for India. Those for England are from ascents made at Benson, Kew and Sealand (lat. 51°–53°N.). Those for India are in three groups: one for Agra, and two others for stations north and south respectively of 20°N. During the monsoon lower tropopauses are more frequent at the more southerly stations than in the north.

Ballons-sondes at Batavia reached the tropopause on too few occasions to give reliable values, but in the majority of the observations the pressure was between 70 and 110 mb.

LEGACY OF THE ICE-AGE

By C. E. P. BROOKS, D.Sc.

The surface of the globe, and its inhabitants including man, were largely re-made by the great climatic crises of the past million years known as the Pleistocene, or the Quaternary ice age, and there is good reason to suppose that the sequence of glaciation and deglaciation has not yet come to an end. That being so, the study of this period is of very great human interest, but it is also one of great difficulty. Changes of climate on a large scale followed one another with—geologically speaking—bewildering rapidity, and as the continents and oceans had almost reached their present configuration, the traces of the various climatic episodes have hitherto been found only in terrestrial deposits, and tend to be local and disconnected. The evidence is abundant but highly various—glacial moraines, river terraces, wind-blown sands, the former and existing distribution of animals and plants, human archæology, soil structure—in fact almost everything in nature has some bearing on climatic history. One of the difficulties of research is that no one man can master all these subjects, and experts have tended to work independently in their own water-tight compartments, reaching conclusions which are not always compatible with those of others. There has been plenty of individual research; the urgent need now is for collaboration between workers in different sciences to produce a world history of climatic, geographical and biological changes which fits all the evidence and is also physically sound.

In June 1947 the Division of Geology and Geography of the National Research Council in the U.S.A. set up a " Committee on Interrelations of Pleistocene Research," as a start " toward creating lateral communication through these invisible bulkheads that interfere with research progress." The first report of this Committee has now been published by the Geological Society of America under the title " Pleistocene Research "*. It consists of an Introduction by R. F. Flint and eleven contributions by members of the Committee, of which the report on " Biogeography in the Pleistocene," by Edward S. Deevey, Jr., is by far the longest, occupying 102 pages. Deevey's contribution raises some highly interesting problems; for example, south-west Ireland possesses a number of species which require warm winters and yet, to all appearances, contrived to live through glaciation within a few miles of an ice-sheet. In the past these anomalous distributions have often been accounted for by the light-hearted creation of " land bridges," sometimes across wide expanses of ocean, but this easy way out finds no favour with Deevey. It may

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*Committee of Interrelations of Pleistocene Research. Pleistocene Research. *Bull. Geol. Soc. Amer., Rochester N.Y.*, **60**, 1949, p. 1303.

be added that his report includes several very useful tables embodying the latest conclusions about glacial and post-glacial succession and correlation. He remarks that the climate of the three interglacial periods " progressed from cold to as warm as to-day and back to cold again, while the middle one seems to have been the warmest as well as the longest." Other contributions, though shorter, also contain much material of interest to climatologists.

Each report surveys the existing position from the standpoint of the author's own subject; so far they are still disconnected essays and no doubt the next task of the Committee will be to study and collate them. But two points have already emerged: the first is that, in the face of the great difficulty of correlating the deposits in different parts of the world by ordinary geological methods, the most helpful line of correlation is climatic. From earlier geological periods marine sediments greatly predominate, and, with few exceptions, it is possible to assume that two marine deposits which contain the same index fossils are of the same age. That is because ocean temperatures over the world were more uniform than during the Pleistocene, and changed slowly enough for evolution more than to keep pace with them. In the Pleistocene on the other hand the range of climate was much greater, and the changes were so rapid that the only way for most plants and animals to survive was by migration. Hence if two deposits, widely separated in latitude, contain the same assemblage of plants and animals (single species are untrustworthy) the inference is that they are of different ages. Human artefacts are particularly difficult in this respect. On the other hand, the general sequence of climatic events appears to have been closely similar all over the world. The two best known sequences, those of northern Europe and North America, agree so closely that the general correlation is no longer in doubt. Other parts of the world are not so well known, especially with regard to the earlier stages of the ice-age, and there is still some uncertainty. The main difficulty however is in the correlation of events in the glaciated and non-glaciated regions, and here an improved knowledge of world climatology during the Pleistocene would be helpful.

The second point, which is brought out by Fred B. Phleger in a short note on " Submarine geology and Pleistocene research," is that the study of the deep ocean beds now proceeding by means of long cores cut out from the deposits in the depths of the oceans, promises to provide a sequence of changes of sea temperature, free from the breaks and ambiguities which are inevitable in terrestrial deposits, which can be used as a world-wide standard of comparison. The remarkable results already achieved will be familiar to meteorologists from a recent article by C. D. Ovey*.

The general subject of " Climatology of the Pleistocene " is briefly discussed by Helmut Landsberg, who points out the difficulties of the astronomical chronology of the ice-age and the unsatisfactory nature of all " theories " as to the cause of glaciation. Surface data are not enough; we must somehow reconstruct the upper air circulation at various stages of the Pleistocene; the distribution of ash-layers from volcanic eruptions may possibly help here. At present even the circulation above an ice-cap is not fully known. The future contribution of meteorology to the problem of climatic change lies in the close analysis of trends in instrumental observations, and possibly in laboratory

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*OVEY, C. D.; Note on the evidence for climatic changes from sub-oceanic cores. *Weather, London*, **4**, 1949, p. 228.

experiments with models. Landsberg remarks that " the production of an ' ice-cap ' in the laboratory might lend considerable weight to any of the thermodynamic hypotheses proposed."

" Theories " are perhaps rather outside the present scope of the Committee, which is concerned more with the collection and correlation of a wide variety of facts. That may be the reason for the omission from the list of contributors of a solar physicist, but a report on modern views as to possible variations of radiation from the sun, both in quantity and wave-length, would have been of great interest. The part played by solar radiation in climatic changes is still very obscure, first because of the divergent views as to whether the sun is a variable star or not, and secondly because, supposing that variations do occur in either the total radiation or its distribution among wave-lengths, the effect on terrestrial climate is not known. On the one hand we have Sir George Simpson's well known dictum that glaciation can only be accounted for by increased solar radiation, and on the other hand we have the view of many geologists and biologists that the periods of glaciation were accompanied by a world-wide lowering of temperature. The contradiction is often met by the rather vague assertion that an increase of ultra-violet radiation may have changed the pressure distribution at the surface by changing the amount of ozone in the stratosphere, without affecting mean surface temperature. So far as I am aware, however, no one has so far attempted to follow out this idea quantitatively, and, until the solar basis is firmer, it would appear to be a waste of time to try.

Another contribution of interest to climatologists is by H. T. U. Smith: " Physical effects of Pleistocene climatic changes in nonglaciated areas: eolian phenomena, frost action, and stream terracing ". The interpretation of fossil dunes in terms of wind direction is of importance for the study of the circulation of the atmosphere near ice-sheets, and the study of frost action is also of great interest; this report includes an extensive bibliography.

It is obvious that data on the Pleistocene are superabundant, and the Committee has made a fine start in summarizing them and pointing out the difficulties of interpretation. This is a necessary beginning to overcoming these difficulties, and all scientists whose material reflects the past will look forward with interest and expectation to the next report.

METEOROLOGICAL RESEARCH COMMITTEE

The ninth meeting of the Instruments Sub-Committee was held on October 5, 1950. Most of the time of the meeting was spent in considering various aspects of the measurement of meteorological quantities in the upper air. The evidence for a real diurnal variation of temperature in the lower stratosphere was discussed. On the whole it seems probable that the apparent diurnal variation as indicated by radio-sonde measurements cannot all be attributed to radiation errors of the measuring instrument.

The design of future elements (temperature, pressure and humidity) for radio-sondes was discussed and certain lines of investigation decided on, which, it is hoped, will indicate the best way in which to change existing designs.

Further consideration was also given to the use of searchlights for determining the density of the atmosphere at great heights.

The Physical Sub-Committee held its 12th meeting on October 19, 1950. A proposal for laboratory investigation of convection was considered and supported. Some time was also given to a consideration of the mathematical treatment of turbulence based upon observations of temperature gradient in the lowest layers of the atmosphere.

A paper[1] by C. S. Durst and N. E. Davis on the accuracy of geostrophic trajectories was also considered.

[1] *Met. Res. Pap., London,* No. 574, 1950.

OFFICIAL PUBLICATION

The following publication has recently been issued :—

British Rainfall 1948

This volume, which is published by H.M. Stationery Office at £1 1s. 0d., retains the essential features of earlier volumes. It provides a comprehensive summary of the rainfall of 1948 over Great Britain and Northern Ireland, both as regards its incidence during the year and its variation from place to place.

The book is arranged in three parts. Part I consists of eleven chapters dealing with such matters as the distribution of monthly, seasonal and annual rainfall, periods of drought and of wet spells, duration and intensity of rainfall, notably heavy daily falls, evaporation and percolation. The articles are illustrated by numerous maps and a coloured plate showing the relation of rainfall in 1948 to the average. The publication of so much information is made possible by the co-operation of a large body of voluntary observers, who measure the rainfall primarily as a matter of personal interest, and by public authorities—especially the authorities of water undertakings—who find that a knowledge of rainfallis essential to them in their work. Reference is made to the deaths of 61 observers. Of these 23 had kept rainfall records for upwards of 30 years and two for no less than 60 years.

Part II is the General Table of Rainfall and gives the recorded total fall with the number of rain-days and wet-days at about 5,000 stations, together with the names of the observers or other authorities.

Part III contains an article in which Mr. L. C. W. Bonacina surveys the snowfall in the British Isles during the years 1936–45. On the whole this decade was a decidedly snowy one, but the seasonal incidence of snowfall was more normal than in several previous decades, showing a tendency for maximum depth in winter rather than in early spring.

UNITED STATES TECHNICAL CONFERENCE ON AIR POLLUTION

The increasing interest of America in atmospheric pollution was clearly shown by the attendance at the above conference, which was called at the request of President Truman. Over 700 engineers, physicists, meteorologists, biologists and legal experts gathered at one of Washington's big hotels to read papers and listen to discussions on this subject. The British delegation consisted of Dr. Parker, the Director of the Fuel Research Station, Greenwich; Mr. Damon, Chief Alkali Inspector of the Ministry of Health; and Prof. O. G. Sutton, Chairman of the Atmospheric Pollution Research Committee (D.S.I.R.). The Conference (held in May 1950) formed itself into a number of Panels, that of meteorology being under the chairmanship of

Dr. E. W. Hewson, who is, of course, well known in this country, assisted by Dr. Wexler of the U.S. Weather Bureau and Dr. Landsberg.

In his opening address Dr. Hewson gave a summary of what has been done so far in the study of the diffusion of suspended matter. The problem falls into two parts: (i) that of the isolated source, such as a factory chimney, and (ii) that of the dispersion of pollution from an area source, such as a city. Mathematicians, not unnaturally, have tended to concentrate on the first of these problems, and Dr. Hewson spent some time in discussing the formulæ for the concentration at ground level from a single continuous elevated source proposed by Bosanquet and Pearson, and by Sutton, and Lowry. The position seems to be that in overcast windy weather, when the lapse rate is small, all the formulæ provide reasonably accurate predictions, but for large temperature gradients, and particularly for inversions, much remains to be done. In the second problem the classical work is that of Dr. Meetham at Leicester. This, of necessity, tends to be more statistical in its approach.

Dr. Hewson was followed by Mr. K. L. Calder, formerly of the Meteorological Office and now in charge of Meteorology at the Army Chemical Corps Station at Camp Detrick, Maryland, who reviewed briefly the theoretical basis of work done at Porton, namely the derivation of the diffusion coefficient from measurements of the transfer of momentum, as indicated by the velocity profile near the ground. He also gave some very simple theoretical and semi-empirical expressions for concentrations from line and point sources which are probably sufficiently accurate for atmospheric pollution studies.

Prof. Sutton read a paper on the mathematical analysis of the ascent of a jet of hot air in a calm atmosphere, and showed how his formula agreed with the laboratory observations of Schmidt. He also gave an approximate treatment of the same jet in a horizontal side wind, and showed that in these circumstances the reduction in ground concentration caused by adding heat to an elevated source of pollution is directly proportional to the amount of heat put in and inversely proportional to the height of the chimney and the cube of the speed of the side wind.

Mr. Ward F. Davidson dealt with the problem of the design of power stations so as to minimize the effects of pollution in the vicinity of the plant. A specially designed low-speed wind tunnel has been used to investigate the effect of the ratio, (stack height) / (building height), on the stream-lines of the air flow to the lee. In the particular case discussed, reducing the height of the building upwind of the stack increased the concentration of smoke at ground level, a result which was not expected.

Dr. Hans Neuberger of Pennsylvania State College dealt at some length with the relations between concentration of condensation nuclei, the duration and transparency of fogs and the size and number of droplets in a fog. This is an extremely complicated problem and it was evident that, despite the excellent work described, much remains to be done.

Dr. P. E. Church gave an account of the microclimatological installation at the University of Washington. This is mainly concerned with an accurate evaluation of the terms in the heat-balance equation, and therefore with fundamental work so badly needed in this subject.

Dr. J. Z. Holland (U.S. Weather Bureau), who is stationed at Oak Ridge, Tennessee, dealt with the formidable problem of diffusion in hilly country, by adopting the familiar " rough surface " theory of aerodynamics to this case.

The formal session concluded with a most interesting film, shown by Mr. M. E. Smith, of the Brookhaven National Laboratory. This consisted of " lapse-time " records of smoke trails from the mast at Brookhaven. In the early morning the plume is solid in appearance for many miles downwind, illustrating the stabilizing effects of a large inversion. As the sun rises higher in the sky and the inversion gives place to a lapse, the plume first wavers and then breaks up in a most striking fashion. No one, after seeing this film, could doubt that meteorological factors must play a dominant part in determining the intensity of smoke concentration downwind of an industrial plant.

The general impression left on the writer is that America is taking micrometeorology very seriously, not only in relation to atmospheric pollution but in its impact on agriculture and on life generally. So far little that is new or revolutionary has emerged, but it should be remembered that, as yet, the subject is in its infancy in the United States. When the initial phase is over, we may look for some exciting results, if the enthusiasm displayed at Washington is any criterion.

O. G. SUTTON

LETTERS TO THE EDITOR

Low humidity

In the past, several references have been made to instances of abnormally dry air over the British Isles. E. G. Bilham in his book[1] quotes readings of 15 per cent. relative humidity at Cardington on April 1, 1931, and at South Farnborough on July 10, 1934. Since then R. S. Read[2] has added White Waltham (April 15, 1942) to this list and at that time it appeared that 15 per cent. might be the lowest humidity recorded in Britain. Later, A. J. Drummond[3] reported two occasions from Kew Observatory records when humidity was less than 15 per cent.:—

1800 G.M.T., June 3, 1939: 13 per cent.
1515 G.M.T., April 15, 1942: 10 per cent.

E. L. Hawke, in a more recent note[4] draws attention to observations made many years ago by R. H. Barnes of Parkstone, Dorset; there were three days when humidity was less than 15 per cent.:—

	Date	Dry bulb	Wet bulb	Vapour pressure	Dew point	Relative humidity
G.M.T.		°F.	°F.	mb.	°F.	%
1700	April 2, 1892	66·7	47·3	2·5	11	11
1530	May 23, 1901	69·3	49·1	3·2	14	11·5
1600	May 24, 1901	71·6	49·9	2·6	12	9·5

Hawke points out that there may be other instances of very low humidity which have passed unrecorded.

From Meteorological Office stations overseas, J. Durward[5] has referred to an observation made at Heliopolis at 1200 G.M.T. on June 13, 1933, when the dry- and wet-bulb readings were 117·2°F. and 69·2°F., vapour pressure, 3·1 mb., dew point 16°F. and relative humidity 3 per cent. Only recently, Senior Meteorological Officer, No. 1 Meteorological Unit, M.E.A.F., forwarded the following interesting letter on low humidity at Shallufa in the Suez Canal zone (30°03′N., 32°33′E., height 49 ft.)

"At 1300 G.M.T. on April 1, 1950, dry-and wet-bulb readings were 86·2°F. and 55°F. respectively. Using 'Hygrometric Tables'[6] the vapour pressure can be evaluated as 0·9 mb. and the relative humidity as 2 per cent. These tables do not extend sufficiently far to enable the dew point to be determined; it is below 0°F. Using the Bilham slide-rule (tropics), the vapour pressure can be evaluated by extrapolating just beyond the end of the linear vapour-pressure scale and the relative humidity can be estimated by extrapolation on the non-linear scale. Similar values to those obtained from the 'Hygrometric Tables' are given. The dew point cannot be determined from the slide."

Reference to Linke's "Meteorologisches Taschenbuch IV"[7] and the Goff-Gratch Tables 1946 (I.M.O. Resolution 164, Washington 1947) shows that the dew point on this occasion was −10°F.!

Readers will no doubt be interested to learn of other occasions of abnormally dry air; observers at home and overseas are therefore invited to forward details to the Editor and to include a note on the surface wind obtaining at the time and on the synoptic situation leading up to the occurrence in addition to the usual instrumental data.

G. NEEDHAM

May 5, 1950

1. BILHAM, E. G.; The climate of the British Isles. London, 1938, p. 226.
2. READ, R. S.; Exceptionally dry air. *Quart. J. R. met. Soc., London,* **68**, 1942, p. 294.
3. DRUMMOND, A. J.; Abnormally dry air at Kew Observatory. *Quart, J, R, met, Soc., London,* **68**, 1942, p. 292.
4. HAWKE, E. L.; The incidence of extremely low humidity in southern England. *Quart. J. R. met. Soc., London,* **70**, 1944, p. 274.
5. DURWARD, J.; Behaviour of the hair hygrograph at Heliopolis. *Met. Mag., London,* **68**, 1933, p. 137.
6. London, Meteorological Office. Hygrometric Tables. London, 4th edn., 1940.
7. LINKE, F.; Meteorologisches Taschenbuch IV. Leipzig, 1939.

Pilot balloon ascent near cumulonimbus cloud

During the afternoon of July 27, 1940, the writer, while at Wattisham (10 miles west-north-west of Ipswich, Suffolk), followed a "tail" balloon which appeared to enter air currents descending at several hundred feet per minute. At the time of the ascent a trough of low pressure lay over south-east England. From the data available in the *Daily Weather Report*, the general wind was northerly, increasing to about 15 kt. at 6,000 ft. Thunderstorms, with local hail, were occurring over the whole of England south-east of a line from The Wash to Portland Bill. From one of these, 2·48 in. of rain fell in 3¼ hr. at Waldringfield (7 miles east of Ipswich). The cloud which affected the ascent lay to the south of Wattisham, and light rain started about a quarter of an hour after the beginning of the observations and continued, light or moderate, till well after their completion. Thunder was heard from the cloud, but no lightning was observed.

Heights and positions of the balloon were computed in the usual manner at minute intervals. The positions are shown in Fig. 1, and the heights above the station in Fig. 2. These heights give the mean downward speed of the balloon from the 15th to the 18th minutes as about 700 ft./min., to which must be added the rate of rise of the balloon through the air (normally 500 ft./min.),

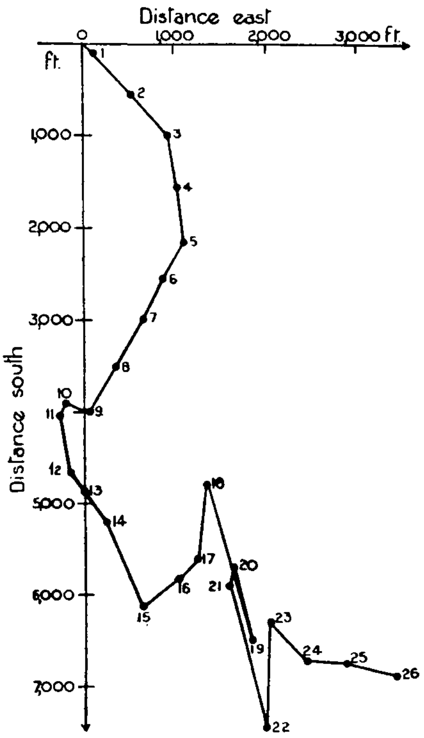


FIG. I—PLAN OF POSITION OF BALLOON

Number by each position indicates time, in minutes, from release.

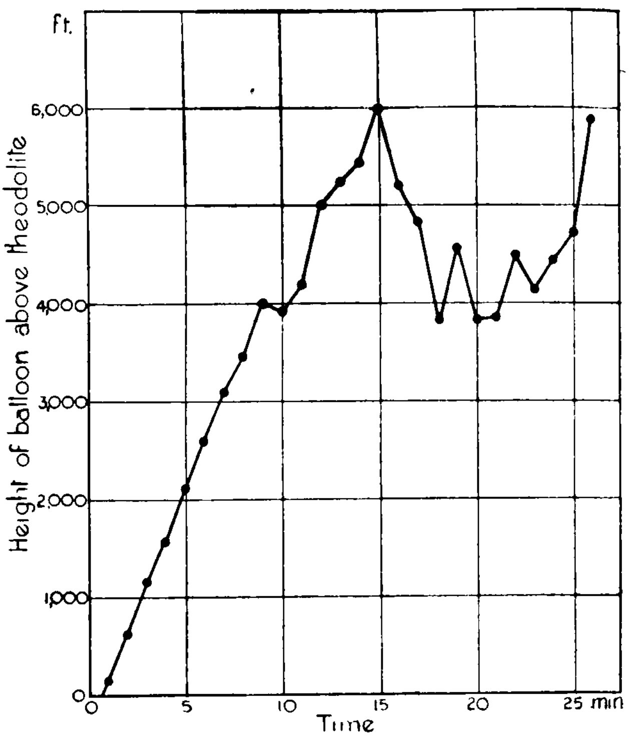


FIG. 2—HEIGHT OF BALLOON AT MINUTE INTERVALS

in order to obtain the speed of the air. But these figures must be considered in relation to possible errors.

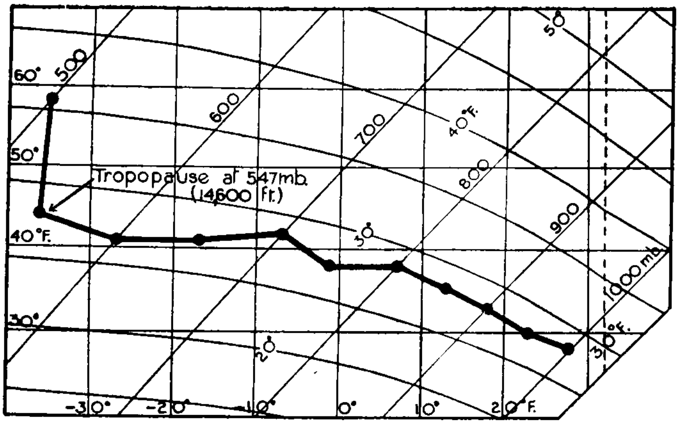
An inclination of the tail of 20° to the vertical would increase the calculated height by 360 ft. and the distance by 450 ft. at the maximum distance observed. The readings at the 19th and 22nd minutes were obviously affected in this way. The weight of precipitation resting on the balloon could force it down through the air, but had this occurred the tail would have gone completely away from the vertical, or above the balloon, and this did not happen. The mean motion over the last three minutes suggests that the apparent downward motion was not due to a leak. Thus there is little doubt that the balloon was affected by downward currents of up to about 500 ft./min. This is most probable during the 9th to 10th and 15th to 18th minutes, and possible at any point from the 18th to the 23rd minutes. The first two occasions appear to have been connected with anti-clockwise motions about 100 yd. and 300 yd. in diameter respectively.

R. H. ELDRIDGE

May 13, 1950

Unusually cold upper air temperatures for April

Extraordinarily cold tropospheric air was reported at Leuchars at 0200 G.M.T. on April 25, 1950, associated with the outbreak of very cold air over the British Isles at that time. It is thought that the temperature readings constitute a record for April.



TEPHIGRAM OF THE LEUCHRES ASCENT, 0200 G.M.T. APRIL 25, 1950

Minimum values of the temperature for England for January and February at various heights have been listed by Miss F. M. Jones, who gives the extreme value of −21°C. (−6°F.) for the temperature at 3 Km. (about 9,850 ft.), whilst the Leuchars ascent shows a temperature of −7°F. at 8,970 ft. (700 mb.). Furthermore, Jones quotes the minimum of −38°C. (−36°F.) for 5 Km. (about 16,405 ft.), which may be compared with the Leuchars value of −35°F. at 14,460 ft. (550 mb.). This comparison of the Leuchars readings of April 25 with the winter extremes for England strongly suggests that the former must be a record or at least a near record for south-east Scotland during April.

R. MURRAY

[The tropopause was at about 14,600 ft. over Leuchars on this occasion, which is extremely low for the British Isles. Over Paris on February 20, 1948, it was at 13,500 ft.*, and, on the same day, the tropospheric air over south-east England was 6–8°F. colder than over Leuchars on April 25, 1950, below the 700-mb. level and warmer by about the same amount above the 700-mb. level.—Ed., *M.M.*]

NOTES AND NEWS

A Chronology of British weather

The late R. W. Jeffery, M.A., F.S.A., Fellow and Tutor of Brasenose, spent many years in compiling a chronology of British weather and embodied the results in two stout volumes of typescript. These volumes have been presented to the Meteorological Office Library by his relatives. Mr. Jeffery gave his work the title " Was it wet or fine? being an account of English weather from chronicles, diaries and registers ".

The ground covered is from Norman times to 1931, truly an immense field. The author usually begins with the Anglo-Saxon Chronicle as his earliest authority and he divides his work into nine chapters each devoted to a particular type of phenomenon. Chapter I, for example, deals with frost and snow, Chapter V with rain and floods, and so on. The records are woven into a kind of continuous narrative connected together here and there with other historical events to give continuity. It is a moot point whether this method of presentation is preferable in a work of reference to a plain straightforward chronology. The author to some extent disarms this criticism by providing in an appendix a chronological list of years with a brief note of the phenomena recorded in each.

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* DOUGLAS, C. K. M.; An unusual vertical temperature distribution over Brussels and Paris. *Met. Mag., London,* 77, 1948, p. 169.

The whole compilation shows immense industry and research. All the events are referred to an authority. Great use is made of the diaries of Pepys, Evelyn, John Wesley, and others for the 17th and 18th centuries, and of the newspapers for the 19th and 20th centuries. In fact the author obviously experiences the chief difficulty of the compiler who would write a complete record of British weather. Up to, say, 1600 A.D. the trouble is to make sure that everything known is included. After that date and especially from about 1750 onwards the difficulty is to decide what to omit. Mr. Jeffery's work is the only one known to me that endeavours to cover the whole historical record with any degree of completeness. It is not so exhaustive as *Geophysical Memoir* No. 70 in respect of the early years of the Christian Era but it is nevertheless a remarkable work of reference and will form an extremely useful addition to the Office Library.

C. E. BRITTON

Visit to the United Kingdom of the National Research Council of Canada De-icing Team

The National Research Council of Canada, in collaboration with the Royal Canadian Air Force, has for a number of years been operating aircraft under the most severe and often hazardous winter conditions to develop anti-icing and de-icing equipment. During the past winter a North Star four-engined aircraft (DC4M) was made available to the Council by the R.C.A.F. to carry out some very intensive flying under icing conditions. Valuable performance data on the electro-thermal method of wing de-icing were obtained, and in order to make this information readily available to government departments and the aircraft industry generally in the United Kingdom, arrangements were made for the de-icing team, with their aircraft, to visit this country for most of August and part of September of this year. While here, the aircraft has been inspected by officials of the departments concerned with work of this type and has also been flown to those firms in the aircraft industry who are concerned. The numerous conferences have included visits to the Meteorological Office at which full information on both sides was exchanged. It is always a pleasure to discuss technical problems with people engaged on similar work elsewhere. As far as the meteorology of ice accretion is concerned, this pleasure has been heightened in the present case by the evident desire of our colleagues from the other side to give any information we wanted, and also by the fact that we found no substantial differences of opinion.

NEWS IN BRIEF

The L. G. Groves Memorial Prize for Meteorology has been awarded this year to F. Pasquill, D.Sc., Principal Scientific Officer, for successfully carrying out, at the School of Agriculture, Cambridge, an important investigation into the exchange of heat and water vapour between grassland and the stratum of air immediately above it. He devised the experimental method to be followed, designed and, in large measure, constructed the instruments, made the observations and carried out the reduction and analysis of his measurements.

This exceptionally varied ability, combined with a fine overall scientific attitude, has yielded results of much interest to the theory of turbulent diffusion and of great value in its application to evaporation problems as affecting agriculture, and the forecasting of visibility and fog as affecting aviation.

The L. G. Groves Memorial Award for Meteorological Air Observers has been won this year by Master-Pilot B. C. J. Calnan, R.A.F., for excellent services rendered as Meteorological Air Observer, No. 202 Squadron, Aldergrove. Master-Pilot Calnan has now completed over 90 meteorological sorties involving 820 hours flying. His technical ability and conscientious recording of scientific data have set a very high standard within the squadron. The meritorious service and devotion to duty displayed by this airman have rendered a most valuable contribution to the success of the long-range meteorological sorties carried out by this squadron.

REVIEW

Das Klima der Vorzeit. By M. Schwarzbach. 9½ in. × 6¼ in., pp. viii + 211, *Illus.* Ferdinand Enke Verlag, Stuttgart, 1950. *DM.* 21.80.

The study of past climates, and especially of those catastrophic episodes known as " ice-ages", has probably been the most prolific breeding ground of theories in the history of science. Most of these theories broke down on some question of fact, for a full consideration of the facts requires a knowledge of almost every subject in and under the sun—astronomy, geology, biology, meteorology, physics, oceanography, are only a few. It also requires a very open mind. Most of the early theorists were men of one idea, and attributed every climatic change through a thousand million years to the action of a single cause, though great climatic changes were surely complex phenomena. Moreover, fifty years ago, when new theories were springing up almost every week, even the facts were inadequately known.

Dr. Schwarzbach's lucid, well illustrated and well documented book on the climate of the past should do much to help future theorists to acquire both an adequate background of knowledge and a due sense of caution. He begins with a good account of the founders and historical development of palæoclimatology and a chapter on the climate of the present in relation to the past. This chapter is short and rather superficial; if the author has a weakness it is in the field of modern meteorology. Then he gets down to business with " The reconstruction of past climates: the methods of palæoclimatology", in which the requisite basis of science has to be reinforced by the deductive faculties of a Sherlock Holmes. In turn he takes us through the evidence for heat and cold, drought and humidity, wind, thunder, seasons and climatic cycles. This section is well informed and up-to-date; for example the change in outlook in the interpretation of biological evidence is clearly brought out. Formerly the local climate of a particular geological period was inferred mainly from the climatic range of the living species of plants and animals which most closely resemble the fossil forms—a procedure beset with many pitfalls. Now greater importance is attached to the physiological character of the whole assemblage—size, rate of growth shown, e.g. by annual layers of corals, shape of leaves, etc., the inferences being based on the reaction of living species to various climates. The chemical and mechanical structure of the rocks themselves also provides a great deal of information. As a result we know the general climate and zonal differences of the various geological periods, and some curious details. One of the oddest deductions, due to Lyell, is that since " fossil raindrops " have the same average diameter as the impressions left by raindrops now, the density of the atmosphere has not changed appreciably. Lithology even gives us a few fossil " upper winds " in the form of distributions of volcanic ash relative to the parent volcanoes. Thus some 270 million years ago, during an eruption, the upper winds at Edinburgh blew mainly from north. In the realm of climatic cycles the most interesting result is the permanence of the sunspot cycle.

This solid body of evidence is then applied to writing the climatic history of the earth period by period since the first well recorded glaciation more than 500 million years ago. This chapter covers 70 pages packed with information. A general summary includes diagrams to show the migrations of the desert belt of the northern hemisphere (salt deposits) and the coral belt, and a diagrammatic representation of earth history.

The author next turns to the subject of causes, in a chapter which he somewhat cynically heads with a quotation from " Faust ": " Don't worry—it was only thought". He runs rapidly through the familiar list—cooling earth, radio-activity, configuration, salt content of the oceans, cloud, carbon dioxide, volcanic ash, continental drift, changes of the earth's orbit, interstellar space, changes of solar radiation. There have been a few more—the whole gamut ranges from the sublime to the ridiculous—but he has mercifully spared us the more ridiculous. His keynote throughout is caution; we do not even yet know enough of the facts to make a final choice. In particular, geologists still tend to think of the whole of a formation, covering many millions of years, as a single episode, though within such a long period there must have been many changes, some of them quite large. He concludes that the Permo-Carboniferous glaciation of the equatorial regions is inexplicable except by movements of the poles, but since then these have played no part, and on the whole he favours R. F. Flint's " solar-topographic hypothesis".

Whatever the causes, the climatic future of the earth is still anybody's guess. As he says, the reader has a free choice between the cheerful optimism of Köppen, " For the next 20,000 years or more the recurrence of an ice-age in the northern hemisphere is excluded by astronomical data," and the gloomier prognosis of Brooks, " Some thousands of years hence ice will again spread out from Norway and the Alps."

C. E. P. BROOKS

BOOKS RECEIVED

Iminência duma " grande " sêca Nordestina. By J. de Sampaio Ferraz. *Rev. brasil. Geogr.*, Ano XII, No. 1. 10½ in. × 7¼ in., pp. 16. Conselho Nacional de Geografia, Rio de Janeiro, 1950 (English summary).

Contribuicao ão Estudo do Clima do Rio Grande do Sul, By F. P. Machado. 11½ in. × 8¼ in., pp. viii + 91. Conselho Nacional de Geografia, Rio de Janeiro, 1950.

Indian Journal of Meteorology and Geophysics. India Meteorological Department. Vol. 1, No. 3, July 1950. Manager of Publications, Delhi, 1950. *Rs.* 2–4 or 3*s.* 9*d.*

Jaarboek, A, Meteorologie, 1946 *and* 1947. Koninklijk Nederlands Meteorologisch Instituut. No. 97, 13¼ in. × 9½ in., pp. xii + 92 and xii + 94. Staatsdrukkerij-en Uitgeverijbedrijf's-Gravenhage, 1949. Price: *fl.* 5.00 each.

Onweders. Optische Verschijnselen, enz., in Nederland. Naar vrijwillige Waarnemingen in 1944. Deel LXV. Koninklijk Nederlands Meteorologisch Instituut. No. 81, 9½ in. × 6¾ in., pp. 58. Staatsdrukkerij-en Uitgeverijbedrijf's-Gravenhage, 1949. Price *fl.* 2.00.

ERRATUM

October 1950, page 281, line 35 :

$$\textit{for} \text{ “}e = \frac{2qH}{(H^2 + y^2)^{3/2}} = \frac{M}{r^{3/2}}\text{” } \textit{read} \text{ “}e = \frac{2qH}{(H^2 + y^2)^{3/2}} = \frac{M}{r^3}\text{”}$$

METEOROLOGICAL OFFICE NEWS

Kew Observatory.—Among the many distinguished Superintendents of Kew Observatory, the name of Whipple has appeared twice. G. M. Whipple held the appointment from 1876 to 1893, and his son, F. J. W. Whipple, from 1925 to 1939. A brother of the latter, Mr. R. S. Whipple, has recently offered to provide a memorial, to be set up in Kew Observatory, in commemoration of past Superintendents. This generous offer has been gladly accepted, and discussions are now taking place with Mr. Ernest Gillick, A.R.A., about the form and design of the memorial. It will probably be placed in the beautiful period room which constitutes the Superintendent's Office.

Mr. Whipple has also kindly offered to establish a memorial to Robert Beckley, his grandfather, who worked at Kew Observatory from 1853 to 1872. Robert Beckley is well known to meteorologists as the inventor of the anemometer and rain gauge which bear his name, and which were in operation at Kew for a long time. The memorial plate to him, which is also being designed by Mr. Gillick, will probably be erected in the octagonal entrance hall of the Observatory.

Forecasting during the War.—The following letter from Marshal of the Royal Air Force, Sir Arthur Harris, G.C.B., O.B.E., A.F.C., appeared in *The Aeroplane* for September 22, 1950.

> **Scotching a Canard**
>
> A statement in your issue of June 9 last has been brought to my notice, in which you repeat an ancient canard that has been circulated on other occasions elsewhere, alleging that I once told a Meteorological Officer that I "would have had over 50 per cent. correct forecasts if I had disregarded the official forecasts entirely."
>
> To this story, in which there is not a word of truth and which has been so often repeated, I would now ask you to give my official denial. It is not only untrue but it is a gross and entirely undeserved reflection on a body of men who rendered sterling service to Bomber Command throughout the War. Upon their devotion and skill I not only placed the utmost reliance, but they proved themselves by their skill the major factor in saving the lives of an unpredictable but large number of air crew, who would otherwise inevitably have perished from the hazards of the European climate.
>
> I would be glad, therefore, if you will make this disclaimer on my behalf and do something towards preventing the further circulation of this silly and lying story, which no doubt causes as much distress to the Meteorologists concerned as it does to me.
>
> ARTHUR T. HARRIS
>
> *Cape Town, S.A.* (Marshal of the R.A.F.)

We offer our acknowledgements and thanks to *The Aeroplane* for permission to give this letter the wider distribution amongst meteorologists which reproduction in the *Meteorological Magazine* makes possible.

Forecasts for food research.—As a result of casual observations made over the past two years, it was suspected by the food research department of Lever

Bros. and Unilever Ltd., that a relationship existed between high humidity and the incidence and spread of a fungus disease, "downy mildew", in spinach plants. As a consequence, the Company decided to try applying protective fungicidal sprays to the spinach plants before the onset of fog or very low cloud in the district where the crop is grown. Special forecasts were supplied by the Central Forecasting Office, which it is understood have assisted towards a solution of the problem.

Examination successes.—We offer congratulations to the following on their recent successes:—

Mr. R. H. Eldridge and Mr. D. W. Newton, who have obtained the M.Sc. degree of London University in Meteorology.

Mr. J. E. Atkins, who passed the Intermediate B.Sc. examination of London University.

Retirement.—The Office is losing the services of Miss E. G. Johnson, who is retiring at the early age of 50 at her own request. Miss Johnson has spent the last thirteen years in the branch which deals with staff: her wide experience and sympathetic understanding of the problems affecting assistant staff will be greatly missed. Our good wishes go with her.

Meteorological Office, Aden.—Mr. J. A. McFarlane, posted to the radio-sonde unit at Aden early this year, is a Highlander and a piper, and speedily found his talents much in demand. His reputation spread and came to the ears of the Sultan of Lahej, a city about thirty miles distant from Khormaksar airfield. The Sultan's private pipers were in need of some coaching since the piper from Scotland, who originally taught them, had returned to his native land. Mr. McFarlane now rejoices in the title of Honorary Pipe-Major to His Highness the Sultan of Lahej and on most Sundays the Sultan's car fetches him to Lahej where for an hour or two he coaches His Highness's pipers. He is accompanied by Sergeant Collins of the R.A.F. Regiment who trains the drummers.

WEATHER OF SEPTEMBER 1950

Mean pressure was above 1015 mb. over a region extending from central Europe and the western Mediterranean across the Azores, the United States and Vancouver, and within this region was above 1020 mb. over a considerable area westward of Portugal. It was relatively low from southern Greenland eastwards to Finland, and over the Greenland Sea, being lowest (about 995 mb.) between Iceland and the Faeroes. Mean pressure was below the normal for September over Europe, except in the south-west of France and in Spain and Portugal, the deficit exceeding 10 mb. over an area including the Faeroes, Scotland, southern Sweden and most of Norway. Deviations from normal were generally small in the north of Africa and in North America.

In the British Isles the weather was excessively wet, exceptionally so in Northern Ireland, Scotland and the western districts of England and Wales. Locally in the Cumbrian mountains the total rainfall for the month was more than 40 in.; in contrast, on the north coast of Kent one or two places received only 1·4 in. The month was very unsettled, with rather frequent and at times severe gales, and sunshine was appreciably below the average on the whole.

During the first five days small secondary depressions or troughs of low pressure moved over the British Isles. Rain fell in most areas, being rather heavy at times in the west and north. It was generally sunny, however, on the 2nd and at most places on the 5th. On the 6th a depression westward of Ireland moved rapidly north-east across Scotland and deepened, causing widespread gales, severe locally, and heavy rain (4·25 in. at Ulpha, Cumberland 4·00 in. at Cwm Dyli, Snowdon, and 3·72 in. at Thirlmere, Cumberland). On the 7th, gales were recorded in the north of Scotland and showers occurred, chiefly in the north-west, but records of bright sunshine were good generally. Again, on the 8th and 9th, a small secondary depression south-westward of Ireland moved north-east to southern Scotland and thence east to Denmark; heavy rain occurred in southern England on the 8th and in Northern Ireland and parts of Scotland on the 10th and 11th.

A spell of very unsettled weather set in on the 13th, when a secondary disturbance south-westward of Ireland moved north-north-east and deepened, subsequently turning north-east. Gales were registered at exposed stations in the west on the 13th and in the north of Scotland on the 14th, while rain fell generally on the 13th and showers, with local thunderstorms in the west, on the 14th (2·89 in. at Fort William on the 14th). From the 15th to the 18th an intense depression moved north-east from mid Atlantic to the south-west of Scotland, and then irregularly north-north-east, to the west of Norway. Widespread, severe gales occurred in the British Isles on the 16th and 17th and heavy rainfall was registered in the west (2·86 in. at Glenbranter, Argyll, on the 16th and 2·74 in. at Glengavel Reservoir, Lanarkshire, on the 17th). On the 19th a small depression off the mouth of the English Channel moved east, while another approached the Hebrides and subsequently moved very slowly across Scotland; rain fell on the 19th and there were showers and local thunderstorms on the 20th and 21st. A complex depression approached our north-west coasts on the 23rd and later moved across the country; very heavy rain occurred in some parts and thunderstorms were recorded in the east of Great Britain on the 24th and 25th (4·14 in. at Hafod Fawr and 4·02 in. at Blaenau Festiniog, both in Merioneth, on the 23rd, 5·15 in. at Llydaw Intake, Snowdon, 4·23 in. at Pandyrddrywyrd, Merioneth, and 3·13 in. at Dundee Harbour on the 24th and 4·31 in. at Llydaw Intake on the 25th). A ridge of high pressure moving east over the British Isles on the 26th was associated with a mainly fair day in England and Wales but further rain occurred later in Scotland and Ireland. In the closing days of the month a depression developed south-westward of Ireland and moved east, later turning north-north-east; rain fell again in most parts of the British Isles and was heavy locally on the 30th.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	76	31	−0·5	196	+9	79
Scotland	71	28	−0·5	257	+9	87
Northern Ireland ...	69	35	−0·5	256	+10	82

RAINFALL OF SEPTEMBER 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	2·47	136	*Glam.*	Cardiff, Penylan ...	6·75	221
Kent	Folkestone, Cherry Gdn.	2·60	110	*Pemb.*	St. Ann's Head... ...	...	...
,,	Edenbridge, Falconhurst	2·98	131	*Card.*	Aberystwyth	5·79	203
Sussex	Compton, Compton Ho.	4·63	166	*Radnor*	Tyrmynydd	9·89	256
,,	Worthing, Beach Ho. Pk.	3·11	145	*Mont.*	Lake Vyrnwy	12·21	338
Hants.	Ventnor, Roy. Nat. Hos.	3·78	152	*Mer.*	Blaenau Festiniog ...	22·14	281
,,	Bournemouth	3·17	136	*Carn.*	Llandudno	4·62	217
,,	Sherborne St. John ...	2·93	143	*Angl.*	Llanerchymedd ...	8·96	305
Herts.	Royston, Therfield Rec.	2.90	154	*I. Man*	Douglas, Borough Cem.	10·38	318
Bucks.	Slough, Upton... ...	2·47	140	*Wigtown*	Port William, Monreith	8·14	279
Oxford	Oxford, Radcliffe ...	2·86	167	*Dumf.*	Dumfries, Crichton R.I.	8·47	313
N'hants.	Wellingboro' Swanspool	3·60	200	,,	Eskdalemuir Obsy. ...	12·16	329
Essex	Shoeburyness	2·37	142	*Roxb.*	Kelso, Floors	4·31	227
,,	Dovercourt	2·53	141	*Peebles*	Stobo Castle	7·17	285
Suffolk	Lowestoft Sec. School...	2·58	132	*Berwick*	Marchmont House ...	4·16	173
,,	Bury St. Ed., Westley H.	3·20	161	*E. Loth.*	North Berwick Res. ...	4·56	218
Norfolk	Sandringham Ho. Gdns.	3·15	152	*Mid'ln.*	Edinburgh, Blackf'd. H.	4·75	232
Wilts.	Bishops Cannings ...	3·85	176	*Lanark*	Hamilton W. W., T'nhill	7·84	293
Dorset	Creech Grange... ...	4·97	182	*Ayr*	Colmonell, Knockdolian	11·33	327
,,	Beaminster, East St. ...	5·00	196	,,	Glen Afton, Ayr San. ...	12·49	320
Devon	Teignmouth, Den Gdns.	3·56	182	*Bute*	Rothesay, Ardencraig ...	11·43	282
,,	Cullompton	4·78	212	*Argyll*	L. Sunart, Glenborrodale	...	...
,,	Ilfracombe	7·39	275	,,	Poltalloch	12·50	274
,,	Okehampton Uplands	8·12	251	,,	Inveraray Castle ...	17·80	227
Cornwall	Bude, School House ...	5·74	232	,,	Islay, Eallabus... ...	10·43	250
,,	Penzance, Morrab Gdns.	6·08	207	,,	Tiree	9·15	247
,,	St. Austell	7·12	223	*Kinross*	Loch Leven Sluice ...	7·31	284
,,	Scilly, Tresco Abbey ...	4·46	174	*Fife*	Leuchars Airfield ...	5·87	304
Glos.	Cirencester	5·05	229	*Perth*	Loch Dhu	16·06	280
Salop.	Church Stretton ...	5·14	244	,,	Crieff, Strathearn Hyd.	8·01	280
,,	Cheswardine Hall ...	...	...	,,	Pitlochry, Fincastle ...	5·83	232
Worcs.	Malvern, Free Library	3·54	183	*Angus*	Montrose, Sunnyside ...	5·96	299
Warwick	Birmingham, Edgbaston	4·85	271	*Aberd.*	Braemar	6·62	264
Leics.	Thornton Reservoir ...	3·15	174	,,	Dyce, Craibstone ...	6·10	252
Lincs.	Boston, Skirbeck ...	3·74	212	,,	Fyvie Castle	5·34	205
,,	Skegness, Marine Gdns.	2·95	163	*Moray*	Gordon Castle	6·22	249
Notts.	Mansfield, Carr Bank...	3·78	205	*Nairn*	Nairn, Achareidh ...	4·18	198
Derby	Buxton, Terrace Slopes	6·40	198	*Inverness*	Loch Ness, Garthbeg ...	7·49	242
Ches.	Bidston Obersavory ...	4·82	200	,,	Glenquoich	20·55	238
Lancs.	Manchester, Whit. Park	...	...	,,	Fort William, Teviot ...	14·85	232
,,	Stonyhurst College ...	7·23	189	,,	Skye, Duntuilm ...	9·62	209
,,	Squires Gate	6·19	228	*R. & C.*	Tain, Tarlogie House...	5·67	248
Yorks.	Wakefield, Clarence Pk.	2·48	155	,,	Inverbroom, Glackour...	14·12	320
,,	Hull, Pearson Park ...	2·69	156	,,	Applecross Gardens ...	11·18	224
,,	Felixkirk, Mt. St. John...	3·33	183	,,	Achnashellach	15·87	231
,,	York Museum	2·65	163	,,	Stornoway Airfield ...	7·09	189
,,	Scarborough	2·38	133	*Suth.*	Loch More, Achfary ...	19·35	337
,,	Middlesbrough... ...	2·33	140	*Caith.*	Wick Airfield	4·81	192
,,	Baldersdale, Hury Res.	5·32	213	*Shetland*	Lerwick Observatory ...	5·58	185
Norl'd.	Newcastle, Leazes Pk....	3·08	156	*Ferm.*	Crom Castle	6·97	250
,,	Bellingham, High Green	5·60	233	*Armagh*	Armagh Observatory ...	5·57	226
,,	Lilburn Tower Gdns. ...	3·93	167	*Down*	Seaforde	6·23	227
Cumb.	Geltsdale	6·07	217	*Antrim*	Aldergrove Airfield ...	5·98	241
,,	Keswick, High Hill ...	14·51	343	,,	Ballymena, Harryville...	8·69	279
,,	Ravenglass, The Grove	8·59	255	*L'derry*	Garvagh, Moneydig ...	8·26	278
Mon.	Abergavenny, Larchfield	3·79	162	,,	Londonderry, Creggan	8·41	255
Glam.	Ystalyfera, Wern House	13·54	310	*Tyrone*	Omagh, Edenfel ...	8·86	290

M.O. 533 AIR MINISTRY

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ESKDALEMUIR OBSERVATORY

By J. CRICHTON, M.A., B.Sc., F.R.S.E.

Early in the present century the extension westwards from London of the tramway system caused so much artificial magnetic disburbance at Kew, that it was decided to establish another observatory where, as far as could be foreseen, magnetic recording would not be interfered with in the same way. A committee of the Royal Society selected Eskdalemuir for this purpose; work was put in hand, and the Observatory opened in 1908. So far no encroachment by artificial disturbance has taken place.

The Observatory lies in the north-east corner of Dumfriesshire, near the source of the Black Esk and the White Esk, streams which later join and flow on to the Solway Firth as the River Esk. The site, about 11 acres in extent, is on a rising shoulder of moorland, sloping from north-west to south-east, some 17 miles from Langholm and 18 miles from Lockerbie. The general sweep of the countryside may be gleaned from the photograph facing p. 344, taken looking westwards from an aeroplane flying at a height of 500 ft. In the top right-hand corner of the photograph may be seen "Ettrick Pen", a hill four or five miles distant and rising to 2,259 ft. above mean sea level; the Observatory itself is about 800 ft. above mean sea level.

From the beginning the principal functions of the Observatory have been the study of (*a*) terrestrial magnetism, (*b*) meteorology, (*c*) atmospheric electricity, and (*d*) seismology (until 1925); and for this purpose instrumental equipment has always been of high quality. In 1925 the seismological equipment was transferred to Kew Observatory.

The work in terrestrial magnetism consists largely of the maintenance and study of continuous records of the earth's magnetic field. The records or magnetograms are photographic and are obtained from three sets of magnetographs, namely a slow-run la Cour set of high sensitivity with a traversing rate of 15 mm./hr., a quick-run la Cour set, also of high sensitivity, with a traversing rate of 15 mm./5 min. and a Kew Adie set of low sensitivity with a traversing rate of 15 mm./hr. The second of these sets enables the times of incidence of various movements to be more accurately determined than with the standard set and the last, owing to its low sensitivity, is of value during very disturbed magnetic conditions, permitting large movements being recorded and easily followed. The elements recorded in each set are horizontal force (H), declination (D) and vertical force (V).

The magnetographs are located in a large underground house, the entrance to which can be seen clearly near the centre of the grounds in the aerial photograph. It is constructed of non-magnetic material and consists of two chambers with encircling corridors, each chamber being about 29 ft. long, 24 ft. broad and 10 ft. high. This form of housing the magnetographs was adopted with a view to minimizing temperature variations, and from the outset the daily temperature variations were almost completely eliminated. It was not until the introduction of thermostatically controlled electrical radiators in 1936 that the seasonal temperature variations were brought under control. Prior to the introduction of electricity, paraffin oil or acetylene lamps were used for illuminating purposes and these gave rise to problems of condensation and ventilation.

Magnetographs are delicate instruments and great care must be exercised in determining their scale values and the values of the elements they record. The scale values are determined at the instruments themselves, while the values of the elements are determined in what are known as " absolute huts ". The huts, like the underground house, are of non-magnetic construction and the two at Eskdalemuir are located, as far away as possible from all other buildings, at the northern end of the enclosure (see photograph). The hut in general use is that in the north-east corner and the instruments employed are seen in the photograph facing p. 345; on the right is the Kew magnetometer used in the determination of D and occasionally H, in the centre the Schuster-Smith coil, for H, and on the left the Schulze dip inductor, for I (inclination) and thence V from the relation, $V=H \tan I$. Recently this standardizing equipment has been increased by the addition of three quartz-fibre horizontal force magnetometers (Q.H.M.'s) and a vertical force balance magnetometer (B.M.Z.), designed and constructed in Denmark. The Q.H.M.'s and the B.M.Z. are easily transportable and will be used for the comparison of Eskdalemuir standards with those of other observatories.

The hourly and other values measured from the standardized magnetograph records are tabulated, summarized and discussed. The results of such work will be found in the *Observatories' Year Book.* With the passage of time the secular variation of the elements becomes important—for example, since the opening of the Observatory D, at Eskdalemuir, has changed almost at a uniform rate from just over 18°W. to between 11° and 12°W. Hourly values of magnetic declination are published weekly in the *Colliery Guardian* and the *Iron and Coal Trades Review*, this service, which has been in operation since 1927, being for mining surveyors. Alongside the Eskdalemuir data in these journals the corresponding data are given for Greenwich (Abinger). Mining surveyors and others interested are also supplied at a nominal charge with contact prints of the original magnetic records. From time to time magnetic information is passed to the National Physical Laboratory, the Radio Research Board, various University and allied bodies, while the Astronomer Royal notifies the Observatory of the passage of large and active sunspots across the surface of the sun, these not infrequently being accompanied by terrestrial magnetic disturbance.

For a period of years, in addition to the above magnetic work, experimental work was carried out, intermittently, on the rate of change of vertical magnetic force. This was done, on an open time-scale, by photographing the indications of a galvanometer conneted to a large loop laid horizontally on the moor outside the Observatory grounds.

Turning now to the meteorological side of the routine, the work here is that of a first order station. At the outset the principal tasks were chiefly recording, tabulating and analysing, but, after the transfer of the control of the Observatory in 1910 from the National Physical Laboratory to the Meteorological Office, the meteorological routine has been gradually extended. Nowadays, telegraphic reports are sent to the Central Forecasting Office ten times a day (seven on Sundays).

In addition to the normal eye-reading and autographic equipment to be found at such a station, there are a photographic barograph and a photographic thermograph (wet-bulb and dry-bulb thermometers). The photographic records, as in the case of the magnetograms, require to be standardized; for this purpose control readings are taken three times each day. In case of failure of photographic records, pen records are available. There is also a Hellmann-Fuess snow-gauge for measuring the amount and rate of snowfall and a Jardi rate of rainfall recorder. A night-sky recorder is maintained in operation and, on behalf of the Department of Scientific and Industrial Research, an atmospheric-pollution recorder. For a period, observations of atmospheric ozone were made with a Dobson ozone spectrophotometer. Equipment for measuring direct and diffuse short-wave radiation on a horizontal surface from sun and sky has been installed.

In atmospheric electricity a continuous photographic record of atmospheric electrical potential is maintained and standardized by means of a quadrant electrometer connected to a polonium collector. Before the polonium collector came into use, a collector of the Kelvin water-dropper type was in use. The meteorological and atmospheric electrical observations, tabulations and observed results are published in the *Observatories' Year Book.*

The buildings at the southern edge of the enclosure (on left-hand side of aerial photograph) are Rayleigh House, the main office block and Schuster House. Just to the outside of the enclosure are Shaw and Glazebrook Houses and to the north-west of these, but inside the enclosure, lie the garage, battery and charging house and the handyman's cottage. The main house names commemorate the distinguished scientists associated with the foundation and early days of the Observatory. As may be gathered from the photograph, the Observatory forms an isolated community on its own. Such isolation, however, presents its own difficulties with staff—the accommodation is strictly limited and it has always been difficult to keep the work within the capacity of the staff. It may be said that those who have served at the Observatory look back with something akin to affection to the days they spent amongst the hills. Amongst their number may be listed three Fellows of the Royal Society, and, of the present staff of the Meteorological Office, two Deputy Directors as well as many other senior members of the staff. The isolation, in the early days, when motor transport was not available, did not seem so great as it does now—this may appear a paradox, but as recreation becomes ever more communal in character, the individual tends to lose his ability for private amusement and study. However, the isolation has its advantages—did not a prophet in the Old Testament find advantage in withdrawing occasionally from political life and musing under a juniper bush? Former members of the staff will be pleased to hear that Miss K. Mackay and Mr. W. J. Hogg are still at the Observatory.

No note about the Observatory and its work could be complete without reference to the late Mr. John B. Beck. Mr. Beck joined the staff as a boy clerk in May 1913, and, apart from a period in the Forces in the first world war, served continuously until the time of his death on March 8, 1950. Mr. Beck will be remembered with affection by all who came in contact with him.

WINTER GALES AND HEBRIDEAN SHIPPING

By D. L. CHAMPION

In a letter written last February, Capt. J. MacInnes, M.B.E., Master of the R.M.S. *Lochness* (777 tons) plying between Oban and the Outer Hebrides, mentioned that the gales of the winter 1948–49 were among the most severe and persistent he had experienced in Hebridean waters. The storminess of this particular season is also referred to in a paper on " The Parish of Barra " by Peggie M. Hobson in the *Royal Scottish Geographical Journal*, in which she states the winter of 1948–49 was " the wildest for many years in the Hebrides".

Reports from the *Oban Times*, summarized below, indicate the severity of these gales and their effect on shipping.

Saturday, January 1. A heavy gale rose on Monday, sweeping the entire west coast. The mailboat *Lochness* was unable to call at the islands of Tiree and Coll. The steam trawler *Commiles* ran ashore 100 yd. south of Kyle pier on Tuesday evening. A light-keeper at Skerryvore was taken ill on Monday, but the lighthouse tender *Hesperus* with a relief keeper was forced to take shelter at Bunessan owing to the severity of the gale and could not proceed until Friday.

Saturday, January 22. One of the worst gales yet experienced this winter. West-coast mailboats were forced to miss several calls. Trawler *Brecon Bank* driven ashore near Maiden Island, Oban.

Saturday, January 29. Stormy seas prevented the mailboat *Lochness* from making any landing at Barra on Monday. On Wednesday another attempt was made, but the vessel was forced to remain at anchor off the island overnight. The gale continued on Thursday, but on Friday morning the vessel was able to make the pier. On Tuesday she was unable to make her weekly call at Colonsay because of the stormy winds. The island of Eigg was cut off by storms all the week.

Saturday, February 26. The fishing boat *Alliance* was driven aground near Drimnin, in the Sound of Mull. The mailboat *Lochness* on her inward run was forced to miss two calls and to abandon her weekly run to Colonsay. The steamer *Loch Seaforth* was unable to reach Kyle pier and was forced to remain at anchor outside. The crew of the *Lochearn*, which arrived 1½ hr. late from Harris on Tuesday, said it had been their worst crossing of the Minch for many years.

It was thought that the gales of this winter merited further investigation, and accordingly available data were extrated from the *Monthly Weather Report* for the following stations : Cape Wrath (8 yr.), Duntulm, Stornoway, Tiree and Oban (13 yr.), and, in addition, reports from Barra and Benbecula were available for the past six winters.

The map, Fig. 1, shows the geographical situation of these stations, against which are shown three sets of figures. The figure in the circle is the average number of winter gales (December to February inclusive), the larger type upper figure is the number experienced in the winter of 1948–49, and the

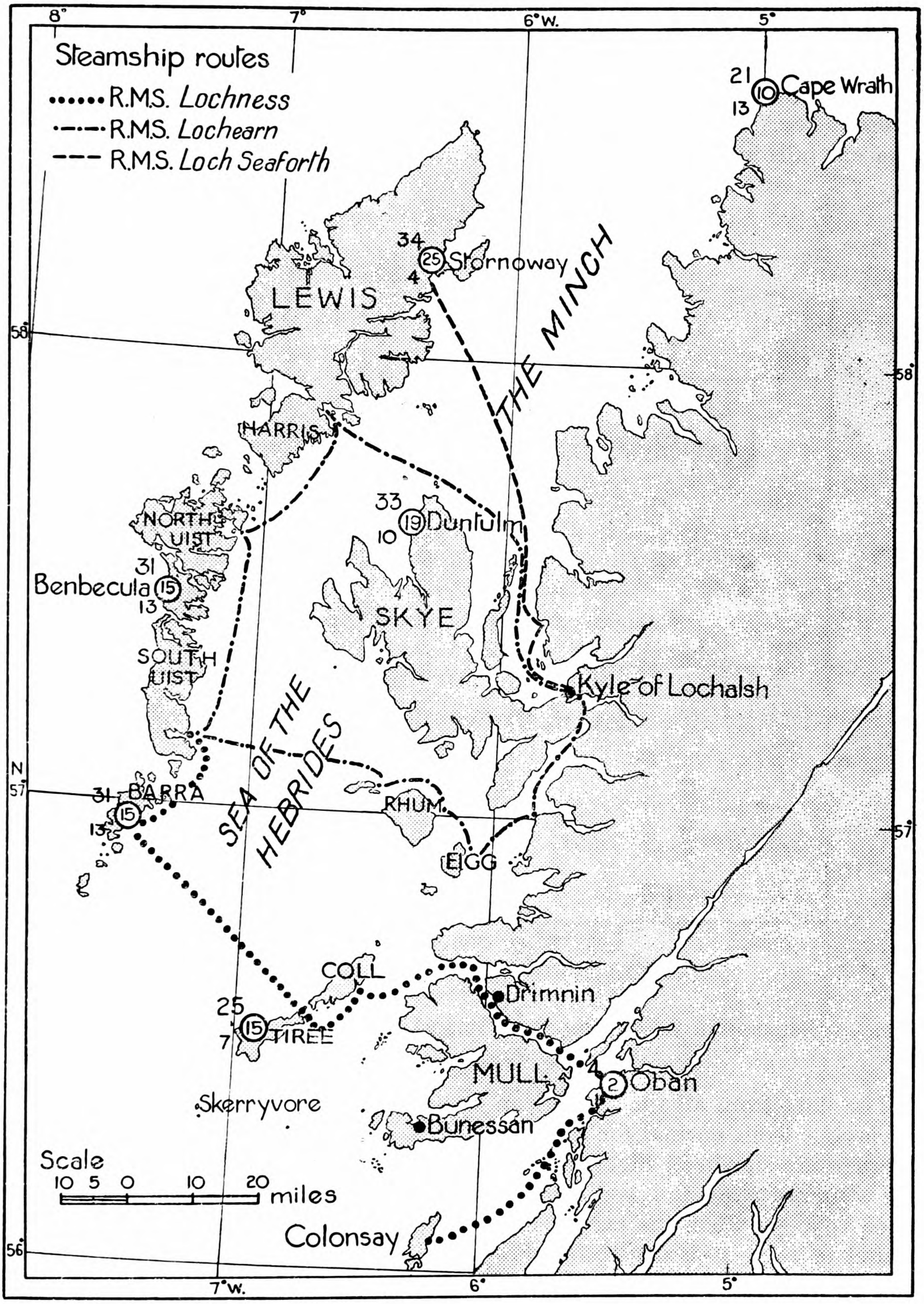

8°
7°
6°W.
5°
Steamship routes
R.M.S. *Lochness*
R.M.S. *Lochearn*
R.M.S. *Loch Seaforth*
21
10
Cape Wrath
13
34
25
Stornoway
4
LEWIS
THE MINCH
58°
HARRIS
33
19
Duntulm
10
NORTH UIST
31
Benbecula
15
13
SKYE
SOUTH UIST
Kyle of Lochalsh
SEA OF THE HEBRIDES
N 57°
31
BARRA
15
13
RHUM
EGG
57
COLL
Drimnin
25
15
TIREE
7
MULL
2
Oban
Skerryvore
Bunessan
Scale
10 5 0 10 20 miles
Colonsay
56°
7°W.
6°
5°

FIG. 1—GALES IN THE HEBRIDES

lower figure gives the number of gales observed in January 1949. The routes of the respective mail steamers are also indicated.

The seasonal deviation from the average number of gales at the above stations is shown in Fig. 2. It will be seen that at Stornoway the excess of days of gale in 1948–49 was the highest since the winter of 1942–43, at Duntulm it was the highest for the past 13 winters, and at Cape Wrath and Benbecula the highest in the past eight years and six years respectively. At Tiree, apart from the winter of 1946–47, it was the stormiest season since 1936–37. The comparative freedom from gales at Oban, due to the shelter afforded by adjacent hills and islands is well marked.

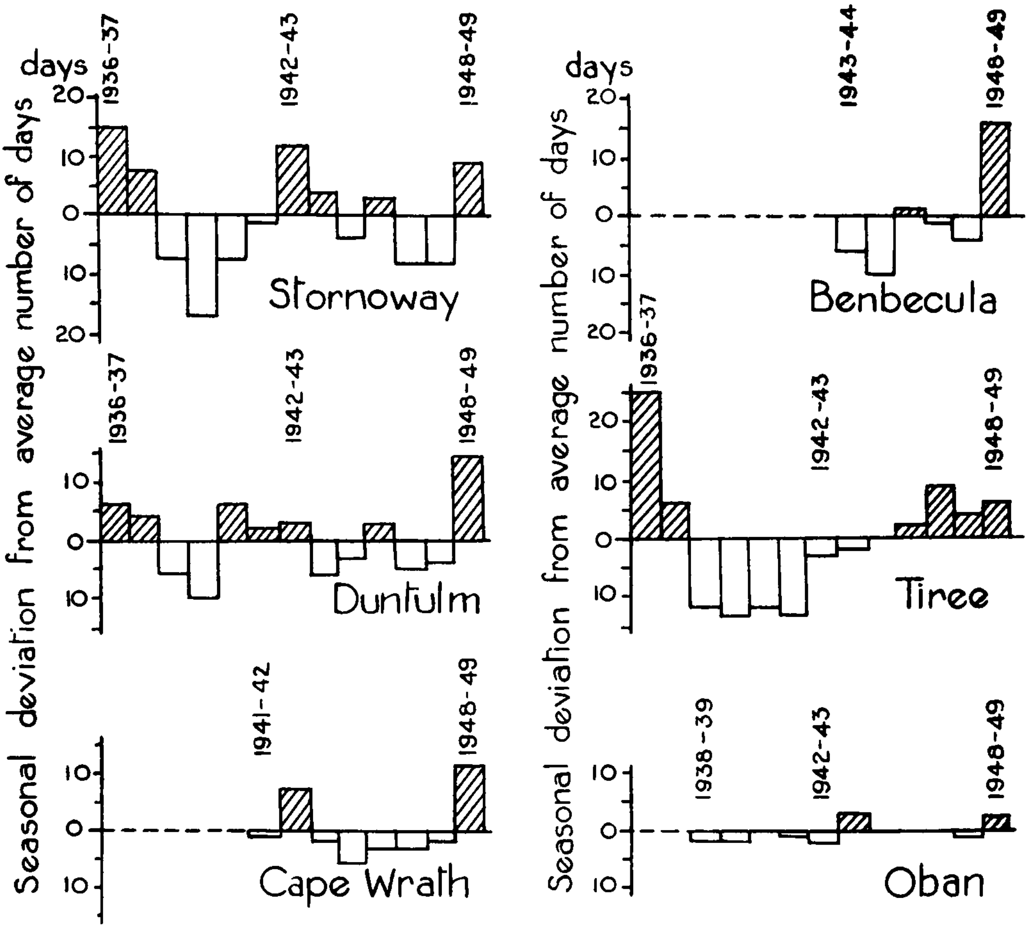


FIG. 2—SEASONAL DEVIATION FROM AVERAGE NUMBER OF DAYS WITH GALE AT INDIVIDUAL STATIONS

The data from all the Hebridean stations have been summarized, and the deviations from normal for the whole area, expressed as a percentage of the average are shown in Fig. 3 for the past thirteen winters. The storminess of the winter of 1948–49 is well marked with an excess of 67 per cent., the highest since 1936–37 when the excess reached 95 per cent. In marked contrast, the winter of 1939–40 is conspicuously quiet, with a deficiency of 69 per cent. in the number of gales.

When one considers how much life in the Hebrides depends on supplies and mails from the mainland, carried by the relatively small mail steamers, the

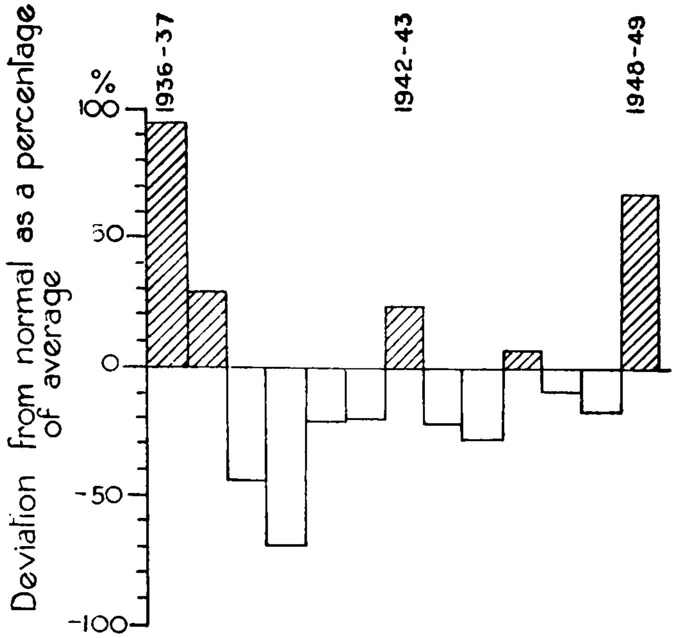


FIG. 3—PERCENTAGE DEVIATION FROM AVERAGE NUMBER OF DAYS WITH GALE AT ALL STATIONS

R.M.S. *Lochness*, *Lochearn* and *Loch Seaforth* (all less than 1,000 tons) the effects of prolonged gales in delaying these ships is not to be disregarded. The route of the R.M.S. *Lochness* in particular is very exposed to the high seas associated with south-westerly gales, especially so on the fifty-miles crossing between Tiree and Barra, where waves exceeding 30 ft. in height are sometimes encountered. The effect on the little ship can well be imagined.

From the above it will be seen that the winter of 1948–49, and January 1949 in particular, will be long remembered for the severity and persistence of gales in the Hebrides.

NOTES ON THE TEMPERATURE AT WHICH RADIATION FOG FORMS

By J. BRIGGS, B.A.

It is well known that radiation fog forms more readily in stable air than in unstable air. The depression of air temperature, below the evening dew point, prior to fog formation appears to bear some relation to the initial degree of stability or instability. In summer fog also appears to develop more easily in air advected from the sea than in air over land, although both may have the same initial dew point. Fog forms more readily over wet ground than over dry, especially if rain immediately precedes sunset.

It is apparent from these considerations that the forecasting of fog is not possible on the basis of screen observations alone. Therefore it was decided to investigate the relationship between fog formation and the temperature and humidity observations up to a height of approximately 5,000 ft.

The observations used were those made at Mildenhall from August 1940 to October 1941, the upper air observations of temperature and humidity being made by aircraft. Until the middle of June 1941 two ascents were made each day, in the morning and in the afternoon; these were taken as representing conditions after and before the radiative cooling. From June onwards three ascents were made each day; morning, midday and evening; during this period the evening ascent was taken as representative of pre-cooling conditions, although in some cases cooling was already showing near the surface and corrections had to be applied. The normal screen observations at Mildenhall served as a basis for estimating the fog point (i.e. that temperature at which fog became or was likely to have become fairly general over the adjacent area). This definition of the fog point excludes the very localized fog which forms in valleys and sheltered places on almost any radiation night. Observations from other stations in East Anglia served as a check of the Mildenhall observations.

Mildenhall can be regarded as an " average " station as regards liability for fog and the area around is relatively free from smoke pollution.

Results obtained.—During the period mentioned there were 43 occasions when radiation conditions were considered to have occurred and when the surface wind was Beaufort force 2 or less for at least two successive observations.

Table I shows the average value of the water-vapour content of the air; any obvious cases of a change of air-mass between the afternoon and morning ascents were excluded.

TABLE I—AVERAGE WATER CONTENT OF THE AIR

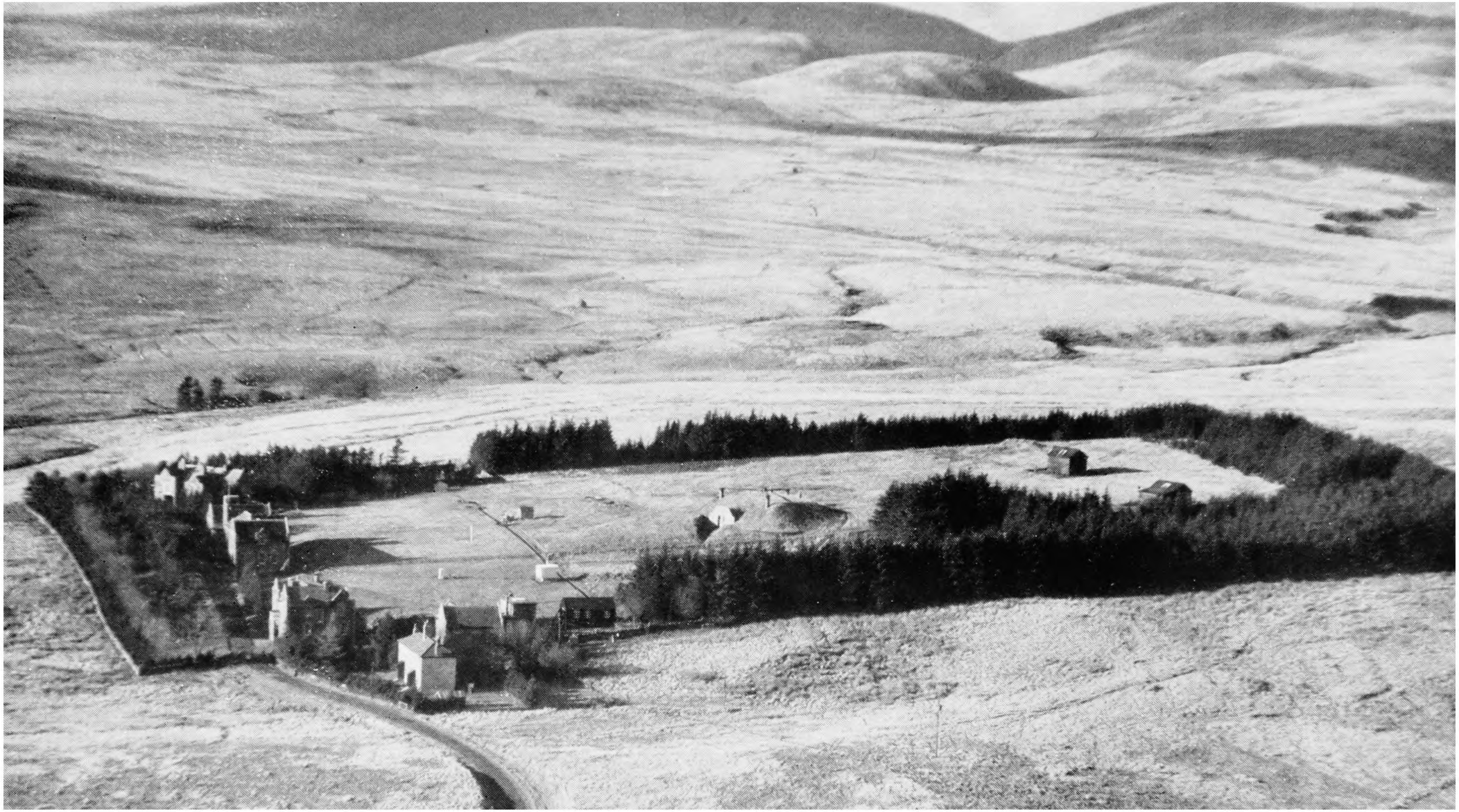
	Water-vapour content at heights				
	Surface	1,000 ft.	950 mb.	900 mb.	850 mb.
	grammes per kilogramme				
Afternoon (or evening) ...	7·6	7·0	6·7	6·3	5·3
Following morning	5·8	5·9	5·7	5·6	4·9

Individual examples were next examined to determine the fog point. To show the effects of varying lapse rate and humidity, Table II was prepared. This shows the number of occasions when the fog point corresponded to the potential dew point at a certain level more closely than to the potential dew point of any lower level. The potential dew point for a certain level is defined as the dew point which the air, originally at that level, would have if it were lowered adiabatically to the surface level.

TABLE II—NUMBER OF OCCASIONS WHEN FOG POINT CORRESPONDED MORE CLOSELY TO THE POTENTIAL DEW POINT AT A CERTAIN LEVEL THAN AT ANY LOWER LEVEL

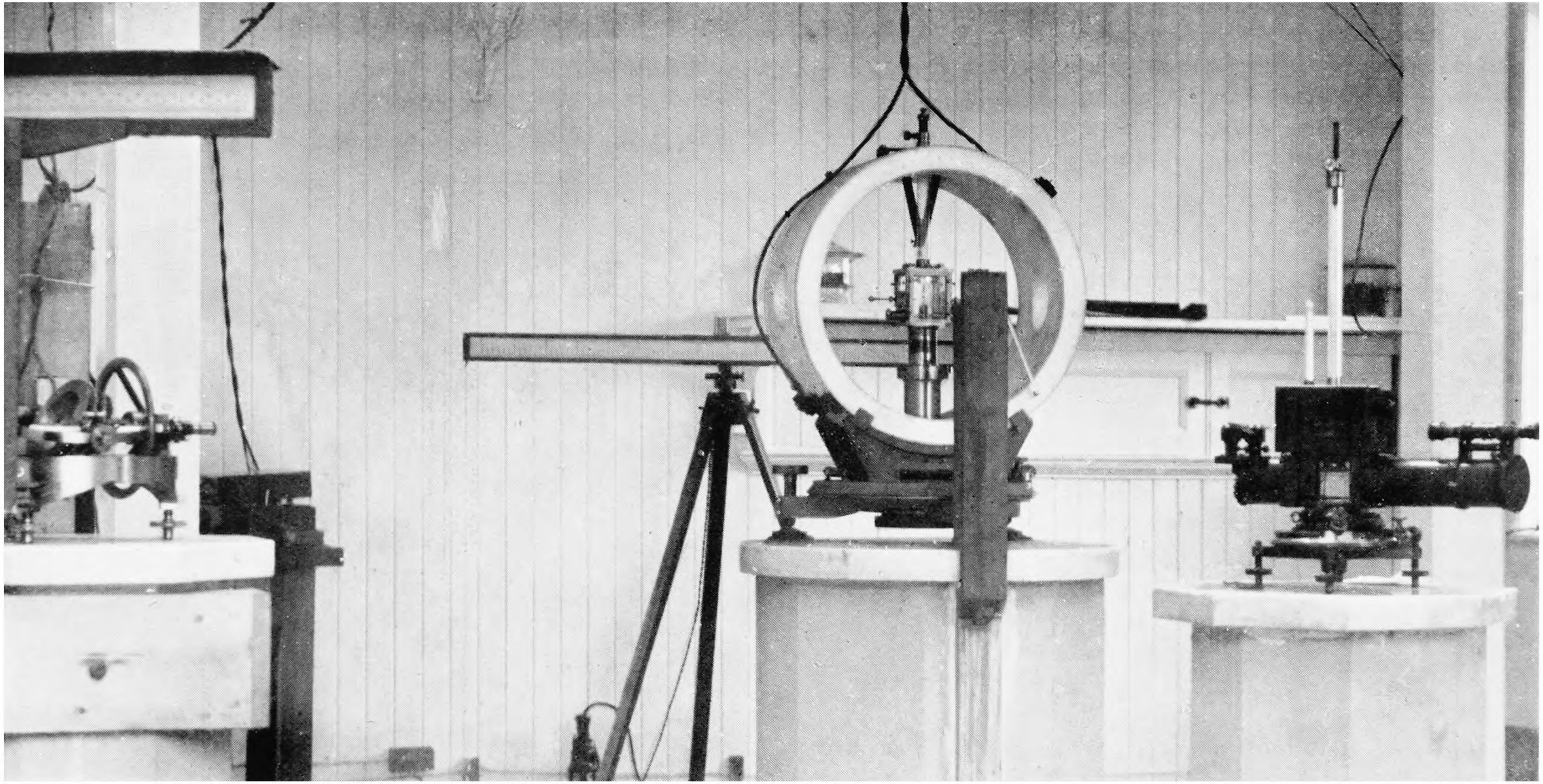
Initial lapse rate	Potential dew point between			
	Surface and 1,000 ft.	1,000 ft. and 950 mb.	950 mb. and 900 mb.	900 mb. and 850 mb.
°F./1,000 ft.				
	(a) All cases			
<3	3	3	1	4
3–4	1	1	3	3
>4	1	1	2	20
	(b) All cases except with hoar frost or wet ground at start of cooling			
<3	3	2	1	1
3–4	0	1	2	2
>4	0	0	1	13

[To face p. 344



AERIAL VIEW OF ESKDALEMUIR OBSERVATORY
(see p. 337)

To face p. 345]



INTERIOR OF EAST ABSOLUTE HUT, ESKDALEMUIR OBSERVATORY

Left to right:—Schulze dip inductor, Schuster-Smith coil, Kew magnetometer
(see p. 338)

For reasons discussed later it was decided to eliminate those occasions on which hoar frost occurred or when the ground was wet at the start of cooling, or when there was an initial inversion of the humidity lapse; the revised figures are given in the second part of the table.

Table I shows that between the afternoon and morning ascents, moisture has been removed up to a height of at least 850 mb. This loss of moisture, if deposited on the ground, would give about 1 mm. of precipitation and is much more than any likely deposit of dew. It is therefore necessary to assume that moisture has been diffused upward into the drier upper layers. It is assumed, as seems reasonable, that the effects of advection are unimportant when averaged over 43 occasions. Table I also shows that an initial humidity lapse is followed next morning by an almost uniform water-vapour content to about 3,000 ft.

Table II suggests that the fog point corresponds fairly well to the potential dew point at a level which depends on the lapse rate (referring to the afternoon ascent). The greater the lapse rate the higher the level required.

Although radiation is the cause of the fall of temperature at the surface the mechanism by which the cooling is extended upwards is not clear. Since conduction can be regarded as negligible there remain two possible explanations: (*a*) radiative exchange between the air and the ground, and (*b*) diffusion by turbulence. Exchange of radiation cannot directly affect the distribution of moisture and diffusion by turbulence remains as the only likely explanation of the results obtained.

With an initial lapse of moisture content with height then turbulence obviously leads to a flux of moisture upwards. When the surface temperature reaches the dew point then the lowest levels begin to lose moisture to the ground. Thus there is a tendency towards uniform distribution of moisture throughout a considerable depth of the atmosphere although the total moisture content is reduced by losses to the ground and to the upper drier layers. This is the effect shown by the figures of Table I, although the depth of the layer through which uniform moisture content is reached is, perhaps, unexpectedly large.

With a uniform distribution of moisture it is obvious that any further cooling at the ground leads to an inversion of the normal hydrolapse so that diffusion would then lead to a flux of moisture downwards which would tend to replace the moisture lost to the ground. Such conditions must quickly produce the necessary degree of supersaturation required for fog formation. As diffusion is the factor governing the moisture exchanges it is reasonable to suppose that the upper limit of the effect depends on the initial lapse rate. The more nearly unstable the air initially then the deeper the layer through which uniform distribution of moisture is reached, the less the average moisture content in that layer and the lower the fog point. This is the probable explanation of the results shown in Table II.

In cases where a marked stable layer acts as a " lid " to low-level turbulence then the mixing will be confined to the layers below the " lid ".

The above results have been used for forecasting with some success. They can be stated briefly as follows:—

(*a*) With a lapse rate throughout the lower layers greater than 4°F./1,000 ft. the potential dew point at 850 mb. can be taken as the fog point.

(*b*) If a more stable layer is reached at any lower level than 850 mb. the potential dew point at that level indicates the fog point.

(*c*) If the air is definitely stable from the surface upwards then the surface dew point is itself the fog point.

(*d*) In intermediate cases the fog point is given by the potential dew point at intermediate levels. With a lapse rate of 3–4°F./1,000 ft. the level of 900 mb. would be used.

Exceptions to these rules are:—

Initial inversion of hydrolapse.—For obvious reasons the surface dew point must be the fog point.

Deposit of hoar frost.—When the fog point obtained by the above rules is very near or is below the freezing point then fog formation generally appears to be delayed. This may be due to more moisture being taken from the air in the form of hoar frost than would be taken out as dew, although the magnitude of this hygroscopic effect is very doubtful. Swinbank has suggested that it is negligible. The lower total water-vapour content at these temperatures may itself be the reason for the delay in fog formation.

Wet ground (e.g. rain or showers after or immediately preceding sunset).—In this case evaporation from objects such as trees may continue after the ground has cooled to the dew point and dew deposition has begun. This extra moisture tends to maintain the low-level moisture content whilst the air is stabilizing and so favours fog formation. The fog point obtained by the above rules would then be too low.

The above rules allow for the difference between air over land and air advected from the sea. Whilst the air over land may have a steep lapse rate to several thousands of feet, the air from the sea may have a stable lowest layer or even an inversion. The " sea air " therefore forms fog more readily although its initial dew point may be no higher than that of the air over the land.

The rules given usually have a margin of safety of one or two degrees Fahrenheit before general fog need be expected. There is normally little ambiguity in applying them.

This note is intended only to indicate what appears to be a practicable method of forecasting although as yet no other theoretical support can be given to it.

A CASE OF STRONG TURBULENCE UNDER AN INVERSION

By J. NEUMANN and U. SCHWARZ
Israel Meteorological Service

A case of unusually strong turbulence in the first three thousand feet above the surface near Lydda Airport (Israel) was reported by several pilots on the morning of April 18, 1950. The pilot of a small aircraft returned from a flight after having been nearly overturned in the air.

The case was all the more interesting since the meteorological flight close to the time of the reported turbulence showed the existence of an inversion of 4·6°C. from the screen up to 3,000 ft. The temperature distribution and winds up to 5,000 ft. as measured over Lydda Airport at 0900 L.T. (0700 G.M.T.) are given in Table I.

TABLE I

Height above sea level	Temperature	Wind velocity Direction	Wind velocity Speed
ft.	°C	° true	kt.
5,000	20·8	160	17
4,000	23·6	150	16
3,000	25·4	130	24
2,000	24·3	120	15
1,500	23·7	...	
1,000	23·1	Calm	
500	22·1	...	
Surface	20·8	290	6

The pilot balloon at 0400 showed north-easterly upper winds, and it would appear that between 0400 and 0900, during which period the winds veered to SE. (see Table I), a trough in the low-level easterlies passed the station from the east.* While the surface charts for the 18th indicated the protrusion northward of the Sudan trough (" Red Sea Trough "), the 700-mb. map for 0400 showed a cyclonic shear in a narrow zone between two anticyclones, a minor anticyclone to the west and a major anticyclone to the east.

Temperature and humidity changes at mountain stations, and the great difference in humidities between mountain stations and stations in the coastal area on the 17th demonstrated that a subsidence inversion was in the course of intensification and lowering. Thus, whilst on the 17th relative humidity at Jerusalem (Rephaim station, 2,526 ft.) dropped to 16 per cent. (with a maximum temperature of 29·1°C.), relative humidity in the coastal area was high. Low stratus developed over the latter and persisted near the coast throughout the 18th, the date of reported turbulence.

One of the salient points of the pilot-balloon ascent (see above) is the strong wind shear between 1,000 and 2,000 ft. suggesting that the Richardson number

$$R_i = \frac{g}{T} \frac{\dfrac{\partial T}{\partial z} + \Gamma}{\left(\dfrac{\partial u}{\partial z}\right)^2 + \left(\dfrac{\partial v}{\partial z}\right)^2}$$

computed for that layer and compared with values of R_i considered as critical for the increase of turbulence may throw light on the intensification of turbulence on the morning of the 18th.

It appears from the meteorological flight that the lapse rate between 1,000 and 2,000 ft. was constant and, therefore, in the computation of R_i $\partial T/\partial z$ can be replaced by $\Delta T/\Delta z$, with $\Delta T = 1{\cdot}2$°C. and $\Delta z = 1{,}000$ ft. $= 3 \times 10^4$ cm. (approximately). If we now accept that there was a calm at the 1,000-ft. level, we may orientate the x-axis of our co-ordinate system in the direction of 300° and obtain that $v = 0$ at 1,000 and 2,000 ft. Next, assume (*a*) that throughout the layer $v = 0$ and, therefore, $\partial v/\partial z = 0$, and (*b*) that it is justified to replace $\partial u/\partial z$ by $\Delta u/\Delta z$; then $\Delta u = 15$ kt. $= 772$ cm./sec. Thus we obtain

$$(R_i)_{1000-2000} = 0{\cdot}70.$$

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* As pointed out by Mr. L. Krown.

In the computation the quantity which is most likely to be in error and appreciably affect the value of R_i is Δu. Any error in Δu will magnify the error in the computed value of R_i, in which the square of Δu appears.

Assume that the correct value of Δu is greater than 15 kt. It is very unlikely that it would be so great as to make our R_i smaller than 0·15; in order for R_i to be 0·15 or less, the wind shear would have to be 32·4 kt at least—an improbably large value in the circumstances. It is still less likely that the shear was so great as to make R_i 0·04 or less. It is recalled that values of R_i of 0·04 and 0·15 were considered to be " critical " by various writers.*

If, on the other hand, we assumed that the correct value of Δu is smaller than 15 kt., the resulting R_i would be greater than 0·70, and *a fortiori* greater than 0·15 or 0·04. It is in place here to quote O. G. Sutton: " Thus at present some support can be found from meteorological data for almost any value of Ri_{crit} between 0·04 and 1 . . . "

METEOROLOGICAL OFFICE DISCUSSION

Ice accretion

The first discussion of the 1950–51 series, held at 11 Carlton House Terrace on October 9, 1950, took the form of a review of recent American research into ice-accretion problems. The opening speaker was Mr. G. A. Corby.

The work considered comprised the results of the Harvard–Mount Washington Icing Research Project[1]† obtained during the 1946–47 winter and also the results of flight researches carried out during the 1945–46 and 1946–47 winters by the Ames Aeronautical Laboratory for the American National Advisory Committee for Aeronautics (N.A.C.A.)[2,3].

Mr. Corby explained how the problem of forecasting the occurrence and intensity of aircraft icing had always been hampered by the lack of data available about the quantities most fundamentally involved, namely the liquid water content and the size of the droplets in clouds. This gap in our knowledge accounted for the apparent paradoxes which were common in reports of aircraft icing. Application of a theoretical treatment of droplet trajectories, due to Langmuir and Blodgett[4], had made possible the measurement of the liquid water content and drop size of icing clouds. The technique consisted in the analysis of the rates of accretion obtained on an assembly of cylinders of various sizes after exposure to the icing cloud. The method yielded also an approximate indication of the type of distribution of drop sizes about the mean effective diameter.

An aircraft icing standard had been adopted by the United States Weather Bureau for work of this type, and, on this standard, one unit of icing intensity was defined as accretion at the rate of 1 gm./cm.^{2}/hr. on a 3-in. diameter cylinder moving through the cloud at 200 m.p.h. with its axis perpendicular to the direction of motion. Icing intensities of 1, 6 and 12 on the standard were defined as the boundary values between trace, light, moderate and heavy icing.

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* SUTTON, O. G.; Atmospheric turbulence. London, 1949. p. 89 *et seq.*

† The index numbers refer to the list of references on page 351.

Application of Langmuir's work enabled the icing rate on the aircraft standard to be calculated once the drop size and liquid water content were known and a graphical representation of the relation between the three quantities was used to demonstrate how a particular icing intensity might be caused by a wide variety of combinations of drop size and liquid water content, and how apparent paradoxes arose in the past because of the lack of knowledge of these quantities.

A comprehensive series of measurements of liquid water content, drop size (mean effective diameter) and the derived variable, icing rate on the aircraft standard, had been made from the summit of Mount Washington, New Hampshire, U.S.A., which is enshrouded in cloud at temperatures below freezing for much of the winter. The mean values obtained for liquid water content, mean effective drop diameter and icing rate were 0·472 gm./m.^{3}, 13 microns and 4·09 gm./cm.^{2}/hr. with standard deviations of 0·269, 5·1 and 3·66 respectively. A statistical analysis had revealed real positive correlations between the icing rate and both the liquid water content and the drop size, but Mr. Corby felt that these correlations had little practical meaning since the icing rate was analytically related to the other two quantities.

The broad relations found between the icing rate and the synoptic situation were mostly peculiar to North American winter conditions, and in any event would be of little value for forecasting owing to the wide variations of icing rate within each situation. Although no connexion had been found between the icing variables and the lapse rate, Mr. Corby considered that such effects had probably been masked by the changes in the physical state of the clouds caused by the forced ascent at the mountain.

An investigation of errors in the rotating cylinder measurements caused by loss of some of the intercepted water before freezing (" run-off ") and loss of fragile rime due to the action of the wind (" blow-off ") had shown that neither cause had significantly affected the Mount Washington results but that " run-off " errors might be large at aircraft speeds.

It had not been possible to confirm or deny from the icing observations at low temperatures the existence of the —41°C. limit identified by Cwilong[5,6] and others as being the critical temperature for the effectiveness of sublimation nuclei in the atmosphere, and no temperature limit could therefore be set below which aircraft icing would be impossible.

Substantial reductions in the liquid water content of clouds had been brought about on some occasions by the introduction of dry ice into clouds covering the summit. A method was demonstrated of estimating from a representative tephigram ascent the maximum possible liquid water content of clouds formed by local convection and low-level turbulence.

The flight researches carried out for the American National Advisory Committee for Aeronautics comprised 557 measurements of the drop size and liquid water content of icing clouds by means of the rotating cylinder method. The ranges of values of these quantities were, generally speaking, consistent with the Mount Washington data.

The idea of forecasting icing intensity on the aircraft standard by using a value of the liquid water content, estimated from radio-sonde data, in association with a mean value of the drop diameter for the cloud type (14 microns for layer clouds and 17 microns for cumulus clouds) had been examined with promising results. In addition, a set of tentative qualitative forecasting rules had been evolved.

In considering the problem of defining the worst icing condition likely to be encountered in a given area, for use by the designers of de-icing systems, two distinct aspects had been recognized: the probable maximum icing condition irrespective of its extent or duration and the maximum continuous icing condition with which de-icing equipment might be expected to deal indefinitely. Values for these two conditions applicable to the United States were quoted. The problem had also been dealt with from a statistical viewpoint and the results specified in the form of the worst icing condition likely to be encountered once in a given number of icing flights over given flight path distances.

The Director, opening the general discussion, drew attention to the difficulties of measuring drop-size distribution, and asked how this quantity had been measured by the U.S. workers. He was surprised that, in view of the work of Cwilong and others on sublimation nuclei, the American work revealed no clear connexion between icing and altitude at great heights. As the duration of an icing instance decreased with the intensity, he wondered whether it was possible to identify a maximum " dosage " of ice deposit.

Mr. Corby explained briefly how the size distribution of the droplets was approximately determined in terms of a set of defined distributions having various degrees of departure from uniformity. It was possible to fly in icing layer cloud more or less indefinitely and this would rule out the possibility of establishing a maximum icing " dosage".

Mr. G. F. W. Oddie quoted a case of icing encountered by the " Comet " jet airliner at a temperature of −60°C.

Mr. Best queried whether it was possible to fly in a supercooled liquid cloud without ice forming. He was doubtful whether the relation between temperature and icing found at Mount Washington would apply to aircraft icing owing to the mountain results being obtained at a fixed altitude. He regretted that the descriptive terms for icing intensity were related to accretion on a fixed-size cylinder.

Mr. Corby felt that reports of no icing in supercooled cloud might well be cases of intensities too small for visual observation.

Mr. Bradbury pointed out that in most pilots' reports icing appeared to be associated with turbulence.

Mr. Corby thought this was because turbulence was common in convective clouds which also gave rise to most significant icing cases.

Mr. D. D. Clark said that icing must vary considerably with the type and speed of the aircraft, and wondered, therefore, how the results were affected by the aircraft and also by the de-icing system in use.

Mr. Corby explained that the type of aircraft and its de-icing equipment did not affect the results, which were obtained from the rotating cylinder measurements and not from the accretion on the aircraft itself.

Dr. Frith quoted from his own experience to substantiate the contention that rotating cylinders pick up snow crystals as well as supercooled water droplets. The amount of ice was not the only important factor since variations in the shape of the deposit affected the aircraft performance in various ways. He thought that the apparent lack of icing in some supercooled clouds might be due to the kinetic heating effect.

Mr. Gloyne explained how Langmuir's theoretical work on droplet trajectories and the rotating cylinder technique were being applied to meteorological research into agricultural problems, e.g. insecticide spraying, etc.

Dr. Palmer (Clarendon Laboratory) showed how the reports of icing at very low temperatures were not necessarily inconsistent with the results of Cwilong's work on sublimation nuclei. An insufficiency in the free atmosphere of the nuclei operative at -41°C. would account for the existence of liquid clouds at temperatures below that limit.

Mr. Wallington drew attention to the fact that aircraft in congested areas might be forced by Air Traffic Control procedures to fly for long periods in icing conditions. He quoted an instance of two Viking aircraft encountering very different icing conditions in the same cloud layer at almost the same time. In reply to a query, he was told that there was as yet no method of predicting the maximum liquid water content of clouds other than cumulus and strato-cumulus.

Mr. B. C. V. Oddie thought that caution would be necessary in applying the results to forecasting in the United Kingdom since they were determined for American winter conditions.

Mr. Corby, replying to a question by Mr. Sawyer, said that errors due to run-off losses must have been considerable in some of the aircraft measurements but no particular investigation of this was mentioned in the N.A.C.A. report.

Dr. Sutcliffe asked whether current Meteorological Office publications were affected by this new work, especially as regards the forecasting of the icing index.

Mr. Corby said that some modification in the guidance given for forecasting icing index would be necessary in the light of the American work.

Mr. Absalom mentioned that this had been allowed for in a new *Meteorological Report* on icing to be issued by the Meteorological Office in the near future.

Points raised by other speakers concerned the connexion between icing and the appearance of clouds, the occurrence of rain ice and the limitations of the rotating cylinder technique as a method of measuring the icing variables.

The Director, in closing the discussion, welcomed the advances which had been made in the complex subject of aircraft icing and commented on the great practical difficulties of the experimental work involved.

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1. Dayton Ohio, United States Army Air Force, Air Material Command. Harvard-Mount Washington icing research report 1946–47. *Tech. Rep., U.S.A.A.F. Air Material Command, Dayton Ohio*, No. 5676, 1948.
2. LEWIS, W.; A flight investigation of the meteorological conditions conducive to the formation of ice on airplanes. *Tech. Note nat. adv. Comm. Aero., Washington, D.C.*, No. 1393, 1947.
3. LEWIS, W. and HOECKER JR, W. H.; Observations of icing conditions encountered in flight during 1948. *Tech. Note nat. adv. Comm. Aero., Washington, D.C.*, No. 1904, 1939.
4. LANGMUIR, I. and BLODGETT, K. B.; A mathematical investigation of water droplet trajectories. *Tech. Rep., U.S.A.A.F. Air Material Command, Dayton Ohio*, No. 5418, 1946.
5. CWILONG, B. M.; Sublimation in a Wilson chamber. *Proc. roy. Soc., London*, A, **190**, 1947, p. 137.
6. CWILONG, B. M.; Sublimation in outdoor air. *Nature, London*, **160**, 1947, p. 198.

METEOROLOGICAL RESEARCH COMMITTEE

The 13th meeting of the Physical Sub-Committee of the Meteorological Research Committee was held on October 26, 1950. A paper by Dr. Pasquill[1], in which the aerodynamic and water-tank methods of estimating natural evaporation were compared, was discussed. Despite the fundamental differences in approach by the two methods, Dr. Penman contended that both methods give substantially correct answers and supported his contention with a number of numerical examples.

Dr. Frith summarized the results of an investigation of inhomegeneities in the upper air on the 50-Km. scale[2], and it was agreed that an attempt should now be made to relate such inhomegeneities to the synoptic situation.

Another aspect of upper air research—the relation of frost point observations to aircraft condensation trails[3]—was also considered.

[1] *Met. Res. Pap., London,* No. 579, 1950

[2] *Met. Res. Pap., London,* No. 583, 1950.

[3] *Met. Res. Pap., London,* No. 576, 1950

ROYAL METEOROLOGICAL SOCIETY

The meeting of the Society held on October 19, 1950, with Dr. R. C. Sutcliffe, Vice-President, in the Chair, was a discussion meeting on the use of films in meteorology arranged by the Society and the Scientific Film Association.

Professor Sir David Brunt, F.R.S., spoke of the great value of films in research work in enabling, in effect, an experiment to be studied many times, and of the light on slow meteorological processes such as cloud formation obtained by showing the film at some 30 times the rate of photographing.

Mr. Jenkins of the Ministry of Education, dealing with the use of films in school teaching, pointed to their value in bringing the subject to life. He considered that, for class-room use, only one idea was needed in a film and that 10 min. was long enough.

Dr. J. S. Farquharson, speaking as one who had been meteorological adviser in the making of some Air Ministry meteorological films for aircrew instruction, pointed out some of the points which needed to be considered in making: such as absolute synchronism of sight and sound, and the necessity for a clear understanding of the purpose of the film and the audience to which it was to be shown before the script was written. He mentioned the high cost of film-making.

Mr. P. J. Meade considered that scientific films could not replace the teacher in the instruction of meteorological staff. He referred to the rapidity with which they went out of date and the difficulty of revision.

Mr. J. D. Chambers of the Scientific Film Association gave some interesting facts on the cost of film-making and the necessity for shooting much more than was actually needed for the final film and drastically editing it.

The documentary film " Spotlight on Weather " made by 20th Century Films at Dunstable and on an ocean weather ship, and the research film " Seeding the Clouds " by Dr. V. J. Schaefer, U.S.A., were then shown. " Spotlight on Weather " gives scenes of work at the Central Forecasting

Office and on an ocean weather ship; and " Seeding the Clouds " gives vivid pictures of cumulus-cloud development and the effect of cloud seeding, either artificially or naturally, by the fall of ice crystals from above.

ROYAL ASTRONOMICAL SOCIETY

Variations in the length of the day

A geophysical discussion on " Variations in the length of the day " was held by the Royal Astronomical Society on November 24, 1950, under the chairmanship of Mr. E. Gold. The regularity in the rotation of the earth provided man with his first master clock; it is only in recent years that standards of time measurement have been improved sufficiently to show, by direct comparison, any variability whatever although slow secular changes have earlier been inferred from astronomical records. The Astronomer Royal, in a brief review of the way knowledge on this subject has been gained, referred to three irregularities. The slow secular lengthening of the day by some 0·001 sec./100 yr. had been satisfactorily explained, as the result of tidal friction, by Taylor and Jeffreys. A long-period fluctuation, related with Newcombe's " great empirical term " in the motion of the moon, still awaits an explanation, and now there is convincing evidence, provided mainly by quartz-crystal clocks, of an annual variation. The earth rotates more quickly in August than in February, giving a total range of about 0·002 sec. in the day's length—over two parts in 10^8.

Dr. R. C. Sutcliffe discussed the possible meteorological causes of this annual variation on the principle of the conservation of angular momentum for the combined system of earth and atmosphere. The atmosphere contributes to the total angular momentum about one part in 6×10^5 so that a variation of 2 parts in 10^8 in the earth would require an opposite variation of about 1·2 per cent. in the atmosphere's contribution. Such a variation in the angular momentum of the atmosphere could be achieved either by redistributing the mass of atmosphere (effectively altering the surface pressure) or by varying the relative motion of earth and atmosphere (effectively altering the zonal component of wind). Dr. Sutcliffe's calculations showed that the effect of surface-pressure changes gave only about 1 per cent. of the required amount, but the effect of varying wind is of the right sense and magnitude and was estimated at about one quarter of the required effect. This estimate was based on upper winds derived from the recently published *Geophysical Memoir*, " Upper Winds over the World"*. This is undoubtedly the best available work on the subject although it already requires revision in the light of new data particularly from those high levels where the maxima of momentum are found in association with the jet stream.

Dr. J. N. Carruthers followed with a discussion of the possible oceanographic effects. He and his colleagues had collected all available data on the change in mean sea level between spring and autumn. There was apparently more water between 45°N. and 45°S. in the northern spring, represented by an average rise of mean sea level by a few centimetres, and this could account for some 10 per cent. of the required effect. Data so far analysed did not permit the study of the annual curve of variation in mean sea level, and if it were found to be sinusoidal and phased in closely to the known curve of variation in the length of the day the total effect might be comparable with the whole effect required. Reference was made to a discussion of the whole subject by Munk and Miller* who concluded, as did Dr. Sutcliffe, that wind variations were the important factor and, further, that oceanographic effect would not account for more than 15 per cent. of the required amount. Munk and Miller found that the entire effect could be obtained from the wind but used only vertical cross-sections through 80°W. and 100°E. as the basis of computation. There is a good deal of synoptic evidence to suggest that these longitudes are not representative of the zonal flow over the earth as a whole and are indeed regions of abnormally large variability of momentum in the northern hemisphere. It may safely be concluded that wind variations provide an important contribution, but until the meteorologists have provided a firmer estimate it would be unwise to dismiss the oceans altogether.

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* BROOKS, C. E. P., DURST, C. S., CARRUTHERS, N., DEWAR, D. and SAWYER, J. S.; Upper Winds over the World. *Geophys. Mem., London*, **10**, 1950, No. 85.

R. C. SUTCLIFFE

LETTERS TO THE EDITOR

Tropical rainfall from cloud which did not extend to the freezing level

In the August 1950 issue of the *Meteorological Magazine* some notes were given on rainfall in the tropics from cloud not extending above the freezing level. Such rain is by no means an infrequent occurrence in east Africa but opportunities of making precise measurements of cloud tops and temperature are rare. The following account of a flight from Nairobi to Mombasa on October 5, 1950, is therefore of particular interest.

The aircraft took off from Mombasa at 0750 G.M.T. on a course of 316°. Over the hills, 20–30 miles inland, the captain of the aircraft noticed rain falling from cumulus clouds some five miles to the south of the track. The cloud base was a few hundred feet above the ground and the tops were 10,500–11,000 ft. above M.S.L. There was no evidence whatsoever of anvil formation and the sky was clear above. The captain of the aircraft took the following psychrometer readings, which are uncorrected for an indicated airspeed of 95 kt.:—

Time	Altitude		Temperature dry bulb	Temperature wet bulb	Remarks
G.M.T.	ft.	mb.	°F.	°F.	
0755	1,000	—	75	72	
	2,500	—	68	68	cloud base
	3,000	904	66	66	
	4,000	873	63	62	
	5,000	841	60	58	
	6,000	811	55	55	extremely turbulent
	8,000	—	48	48	
0813	9,000	729	45	45	
	9,500	714·5	43	43	
	10,000	701	43	41·5	
0819	10,500	—	40	39	cloud heads
0828	10,400	691·5	40	38	
0846	10,500	—	40	38	
0900	10,500	689	40	38	

D. A. DAVIES

East African Meteorological Department, Nairobi, Kenya, October 30, 1950

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* MUNK, W. H. and MILLER, R. L.; Variation in the earth's angular velocity resulting from fluctuations in atmospheric and oceanic circulation. *Tellus, Stockholm*, **2**, 1950, p. 93.

Simultaneous aircraft soundings of temperature and frost point

For several years now the Meteorological Research Flight has made frequent aircraft soundings to heights of about 40,000 ft. to measure the temperature and humidity of the upper air and to make other observations. Recently it has been our practice to make an occasional sounding employing two aircraft in formation, observations being made independently, but as far as possible simultaneously, in each. This provides a check of the instruments and their reliability.

It is thought that readers of the *Meteorological Magazine* may be interested to see the results of two of these " double ascents". Fig. 1 shows the results of a sounding made on the afternoon of August 14, 1950, and Fig. 2 one on the morning of October 5, 1950, both over Farnborough. The comparatively large differences in both temperature and frost point at the three highest levels in Fig. 1 may be explained by the fact that the aircraft were 10–20 miles apart. During all the other observations on both dates the aircraft were close together.

The good agreement of the temperature measurements, which were made using Meteorological Office flat-plate electrical resistance thermometers, was

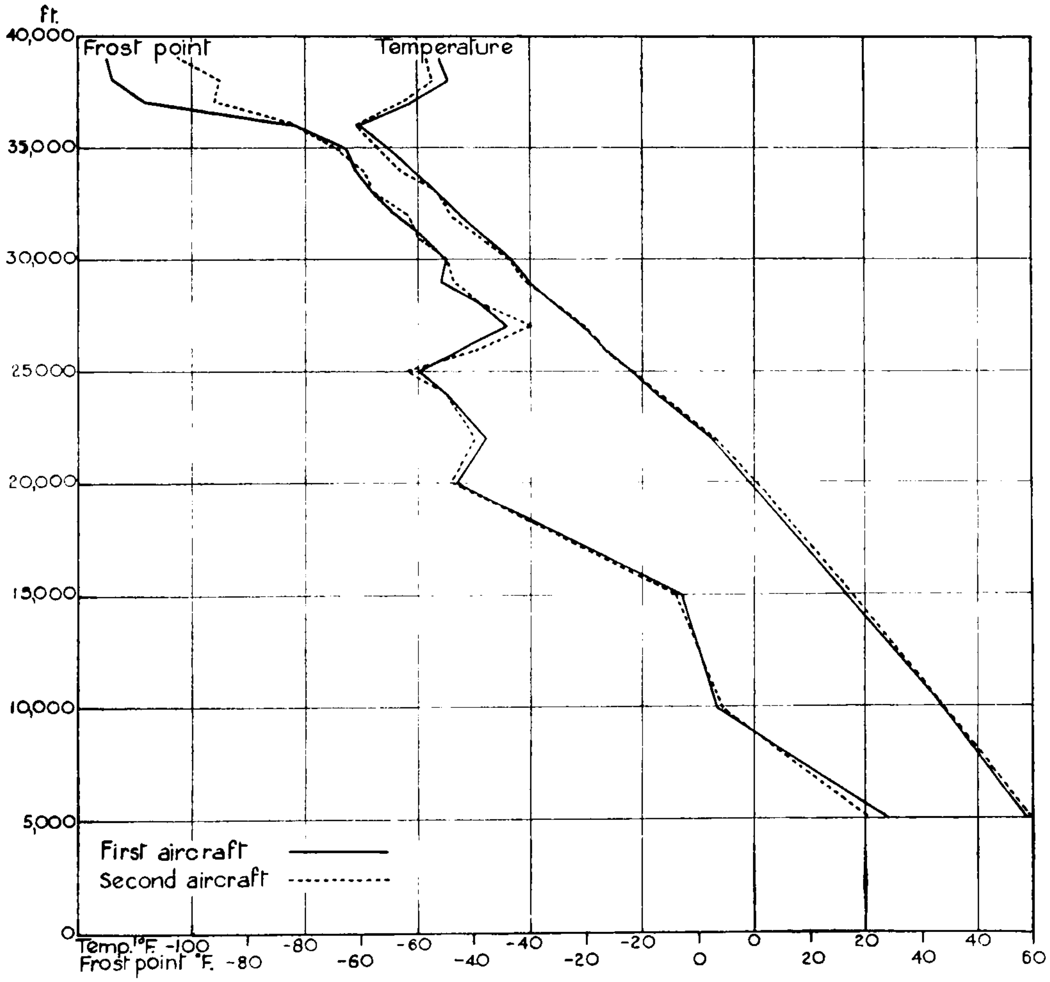


FIG. 1—SOUNDING BY TWO AIRCRAFT IN FORMATION OVER FARNBOROUGH 1410–1540 G.M.T., AUGUST 14, 1950

For clarity the frost-point readings are all displaced 10°F.

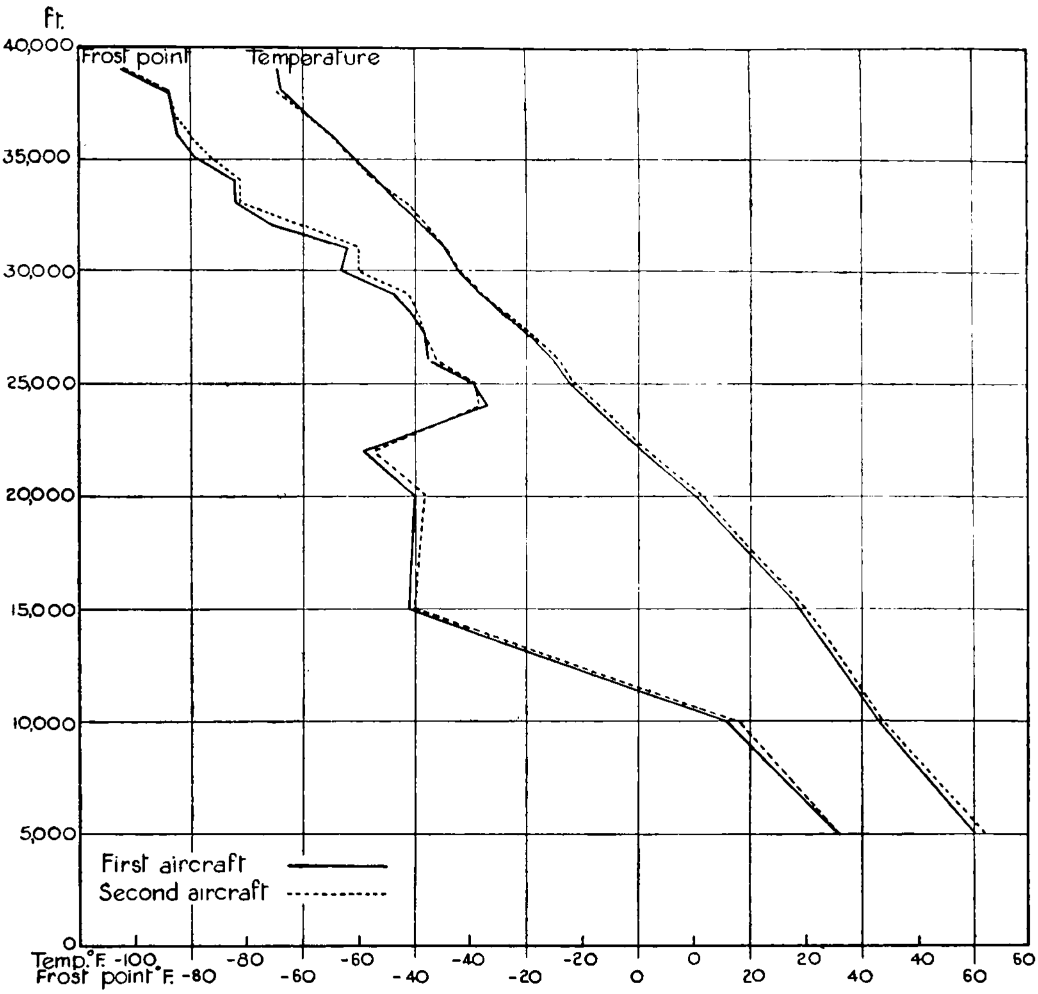


FIG. 2—SOUNDING BY TWO AIRCRAFT IN FORMATION OVER FARNBOROUGH
1015–1130 G.M.T. OCTOBER 5, 1950
For clarity the frost-point readings are all displaced 10°F.

to be expected. That of the frost-point measurements, made by means of the Meteorological Office Mk IIa pressurized aircraft frost-point hygrometer, is more remarkable. This instrument requires considerable practice to operate, particularly at low frost points, but these observations indicate that measurements made by experienced observers are satisfactorily reliable and repeatable.

H. E. SHELLARD

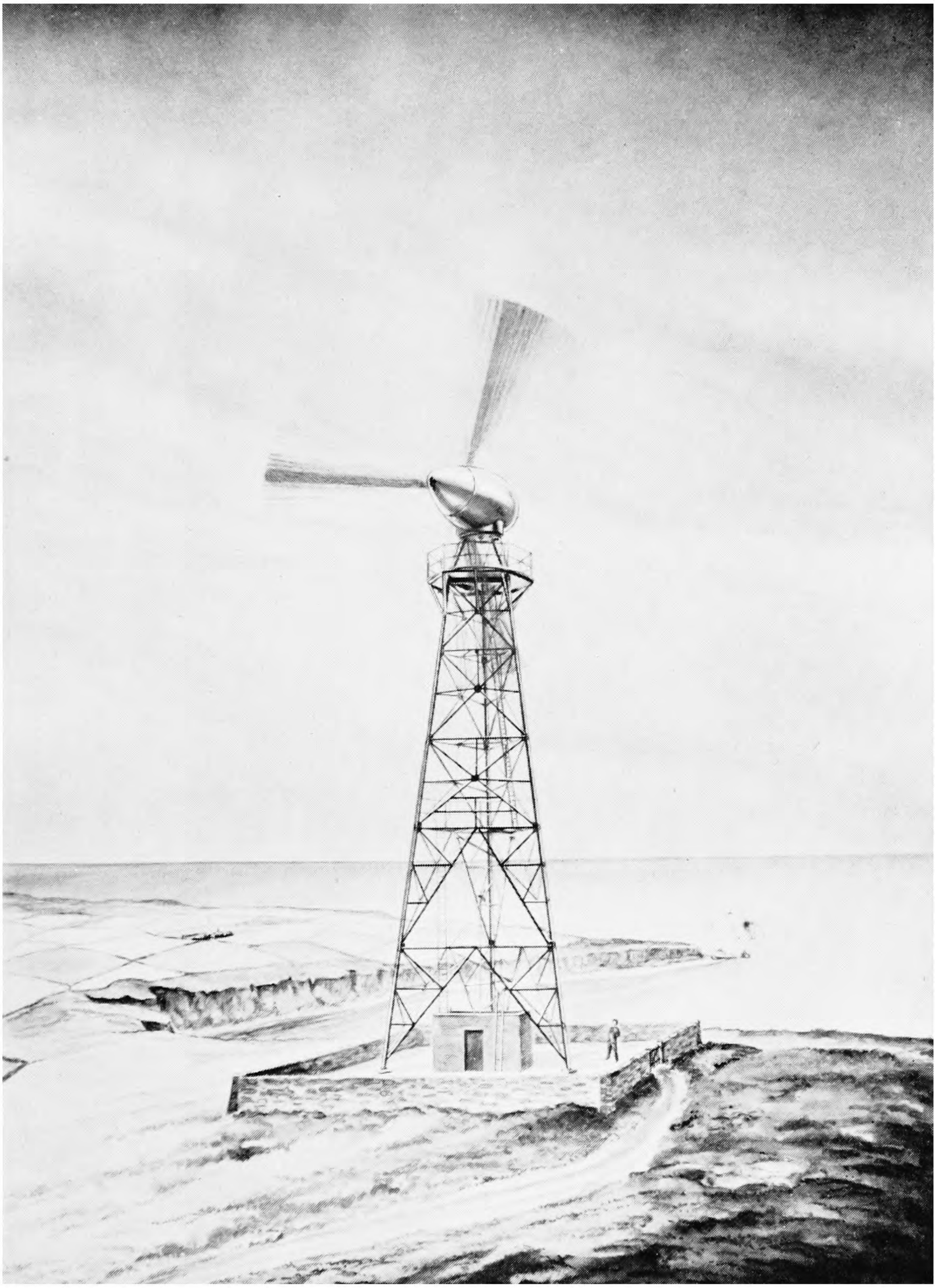
Farnborough, Hampshire, November 9, 1950

NOTES AND NEWS

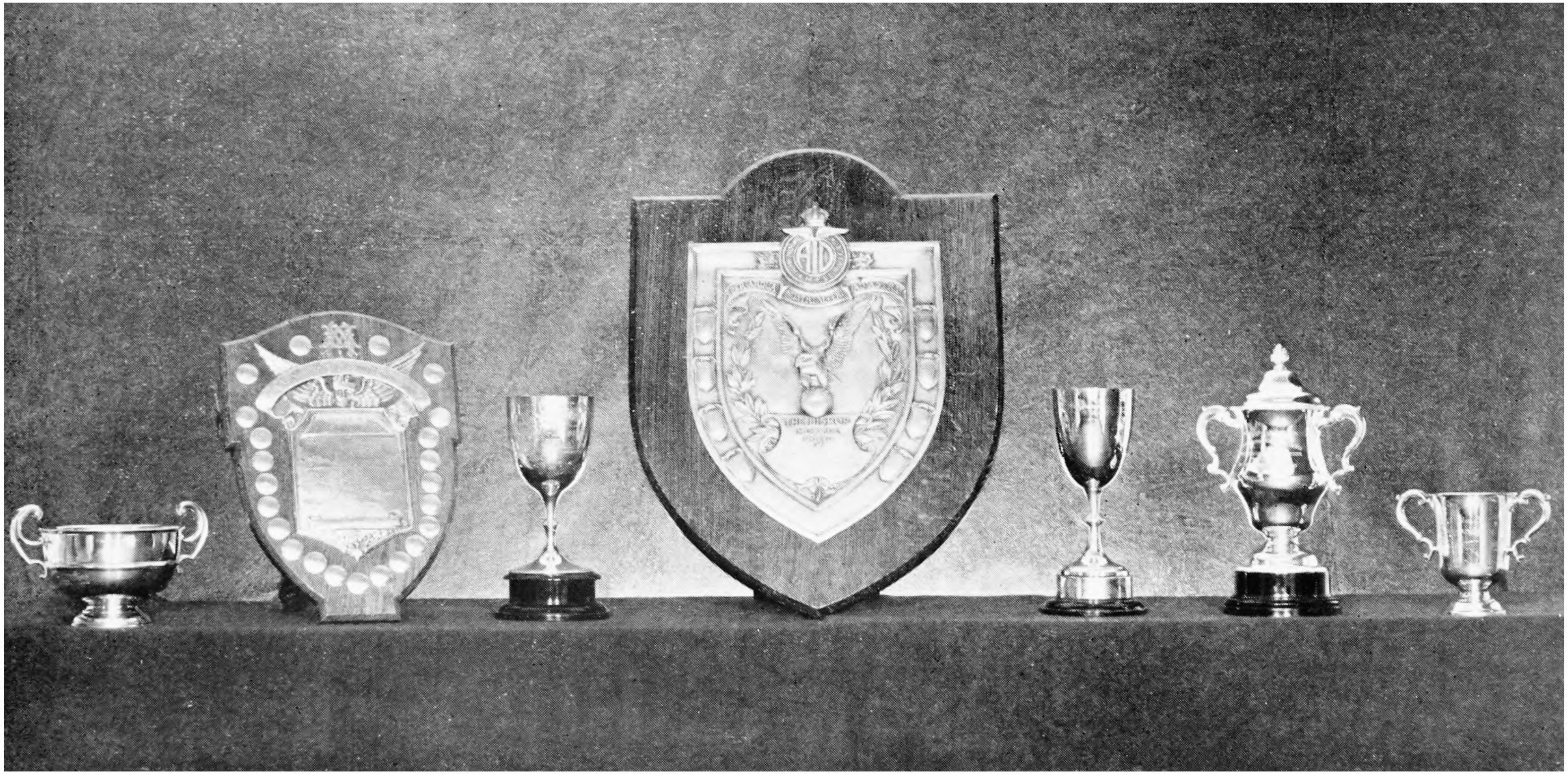
Orkney windmill

Opposite is an artist's impression of the first large-scale windmill in Great Britain for the generation of electricity for public supply. It is being made by John Brown & Co. Ltd., for the North of Scotland Hydro-Electric Board and will be erected on Costa Hill, Orkney.

In northern and western Scotland, a considerable volume of power could be produced from the winds if economical and reliable machines were available



ARTIST'S IMPRESSION OF WINDMILL FOR ELECTRICITY GENERATION ON COSTA HILL, ORKNEY



TROPHIES AT PRESENT HELD BY THE METEOROLOGICAL OFFICE

Left to right.—**Londonderry Cup** for golf; **Halahan Challenge Shield** for the tug of war championship; **Air Ministry Football Challenge Cup**; **Bishop Shield** awarded to the Division which has the best record for the year in Sports activities; **Air Ministry Cricket Challenge Cup; Bristol Challenge Cup** awarded to the Operating Company or Airport Department scoring highest aggregate points at the London Airport Annual International Sports (won by the Meteorological Office, London Airport); **W. S. Jones Memorial Cup** awarded to the Division scoring the highest number of points at the Annual Sports Meeting.

and this experimental windmill has been designed as a first step towards solving the mechanical and aerodynamic problems involved.

The tower will be built of steel and its foundations on solid rock. Each sail will be 30 ft. long. The nacelle, 78 ft. above ground, will contain a gear box and generator and will rotate to keep the rounded end facing the wind.

The rated output of the windmill is 100 Kw. and it will be connected to the Hydro-Electric Board's network on the mainland of Orkney.

Guidance on the meteorological factors concerned has been provided by the British Climatology Branch of the Meteorological Office.

The movement of jet streams and the wind hodograph

A common feature of synoptic charts for levels in the upper troposphere is a jet stream. In it winds of high speed extend for several hundred miles along the track of the wind, but to either side and above and below there is a sharp decrease in velocity. If the air forming a jet stream in the upper troposphere remains at the same distance from the axis of the jet during its passage through the region, then the movement of the jet perpendicular to its axis would be the same as the wind component in that direction. An examination of several jet streams in this respect was made by Mr. T. Shaw in the course of upper air studies in the Forecasting Research Division. The results are briefly described below, because although they do not promise any reliable method of forecasting the movements of jet streams, nevertheless they may be of interest to those confronted with this problem.

The data examined related to six periods during 1949 when jet streams were over the British Isles. The position of the jet stream was estimated on contour charts of the 300-mb. surface drawn at 6-hr. intervals, and hodographs were plotted in respect of the wind soundings from stations near to the axis of the jet. Fig. 1 represents an idealized wind hodograph for a station beneath a jet stream. With respect to the origin at O, the point S represents the direction and velocity of the wind at the surface, i.e. the wind direction is from S to O and the wind velocity is proportional to the length of SO. Similarly the points A, B, C, etc., represent the winds at successive pressure levels at 100-mb. intervals (50-mb. intervals were used in the investigation). The straight section GC defines the thermal wind direction in the jet and is aligned approximately parallel to the axis of the jet. The perpendicular OP from the origin

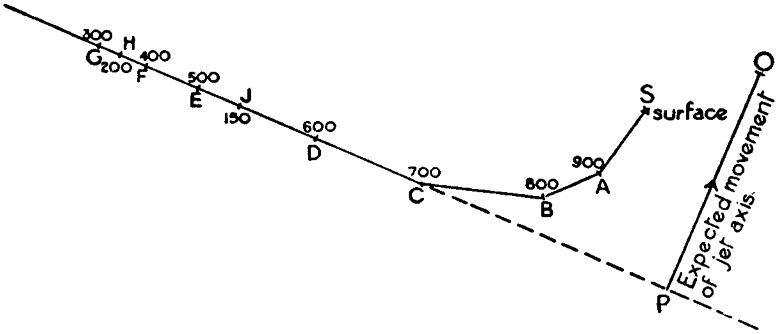


FIG. 1—IDEALIZED HODOGRAPH OF WIND SOUNDING THROUGH JET STREAM

Figures indicate pressures (in mb.) of levels of wind observations.

approximates to the wind component perpendicular to the jet axis. Wind hodographs near the jet streams were examined, a straight line GP was drawn passing as nearly as possible through the representative wind points in and below the jet, and PO was measured.

The direction of movement of the axis of the jet, as suggested by the hodograph, was in good agreement with the observed motion—only one hodograph out of the 53 studied gave an indication in the wrong sense. There was only moderate agreement between the predicted speed of movement and the actual speed of the axis of the jet over 6-hr. intervals—errors were less than 15 kt. in most cases, compared with the average speed of the jet of 20–25 kt. The hodograph component, PO, varied considerably from sounding to sounding within the same jet stream. However, for two of the jets, the mean value of the component PO was calculated for a sequence of several soundings in the same jet stream and good agreement was achieved with the speed of the jet axis as obtained from its displacement over the longer period. In these two cases calculated displacements were 486 miles in 18 hr. (April 4–5, 1949) and 390 miles in 24 hr. (December 5–6, 1949) compared with observed displacements of 450 miles and 410 miles respectively.

There were difficulties in determining the axis of the jet streams; wind observations were rarely made centrally with respect to the jet; also there was occasionally some uncertainty in estimating the value of the hodograph component PO when the features of the wind hodograph were indefinite. The findings of the investigation are, therefore, not conclusive, but there is enough evidence to suggest that the movement of a jet stream perpendicular to its axis is closely related to the component in this direction of the wind within the jet.

J. S. SAWYER

International exchange of views on the operation of ocean weather ships

On September 4, 1950, the U.S. Coast Guard Cutter *Castle Rock* arrived in Glasgow after a spell of duty at ocean weather station ABLE (62°N., 33°W.). Cdr. Graves, Captain of *Castle Rock*, was for many years engaged on ice-patrol duties, was a meteorological adviser to the coast guard authorities at Washington, attended the first weather ship conference in London, and was at the I.M.O. Conferences at Toronto and Washington in 1947. Mr. Hill, of the U.S. Weather Bureau, Meteorological Officer aboard *Castle Rock*, is a veteran sea-going meteorologist, having served in ocean weather ships since their inception.

On September 7, Cdr. Graves and three of his officers, accompanied by Cdr. Frankcom, visited *Weather Observer*, which was at anchor at the Tail of the Bank. They inspected the ship thoroughly, exchanged views with the officers and were entertained to lunch aboard. Later they saw a radio-sonde ascent and an air sea rescue exercise carried out with a force 7 wind. After leaving *Weather Observer* they visited Prestwick airport.

On the following day, Cdr. Frankcom, the shore captain and the Master of *Weather Recorder*, paid a return visit to Cdr. Graves and thoroughly inspected *Castle Rock*. This opportunity of making a personal exchange of views upon the operation of these ships can be nothing but beneficial.

International operation of an ocean weather station

August 23, 1950, in the delightful setting of Bergen harbour, saw the ending of one very pleasant international fellowship, and the inauguration of another which it is hoped will be equally fruitful. The ocean weather station MIKE, off the coast of Norway, is manned by the former " Flower " class corvettes *Polarfront I* and *Polarfront II*, which were converted for the purpose in British Admiralty Dockyards and have been operated jointly by Norway, Sweden and the United Kingdom. In future, as a result of the second ocean weather ship conference, the British responsibility for the operation of this station will be taken over by Denmark and Belgium.

To commemorate this change-over of international responsibility, representatives of the countries concerned assembled aboard the o.w.s. *Polarfront I.* It was interesting to note that two of the Stewards aboard this small ship are women, and their presence aboard was shown in the homely atmosphere of the wardroom.

After the ship's return to Bergen, a dinner was held for the various delegates at which speakers stressed the very amicable relations which had been maintained between the Scandinavians and the British authorities throughout the Anglo-Scandinavian operation of station MIKE.

Geochimica et Cosmochimica Acta

We have received from the publishers, Messrs. Butterworth-Springer Ltd., Bell Yard, London, W.C.2, a copy of the first number of a new journal which bears the title quoted above and which is to publish research papers on geochemistry and cosmic chemistry.

The first number contains articles on the structure of recently fallen meteorites and on the chemical constitution of certain minerals, oceanic waters and sediments.

The British editors are Professor Paneth, F.R.S., Professor Wager, F.R.S., and Dr. S. R. Nockalds. The other editors represent the U.S.A., Sweden and Germany. The journal is to be published in parts at irregular intervals, composing volumes of about 300 pages, priced at £3 10*s*. 0*d*.

REVIEWS

The Flight of Thunderbolts. By B. F. J. Schonland. Size: 8¾ in.×5½ in., pp. viii+152. *Illus.* Geoffrey Cumberlege, Oxford University Press, 1950. Price: 15*s*. 0*d*.

When a distinguished scientist takes the title of a book on the subject of his life's work from a line in the " Mikado " an unusual result may be expected. Dr. Schonland has contributed as much to modern knowledge of lightning phenomena as any other man since Franklin. The results of his investigations were reported to the Royal Society in a long series of papers. Apart from the clue provided by the title, those acquainted with his work might have expected to receive from his hands a co-ordinating account of the results obtained by himself, his collaborators and other workers on the same and related subjects.

The author has decided otherwise. He addresses the general reader and he does so by omitting all mathematics, specialized terminology and detailed numerical information. Instead, he presents his " case history", as he calls it, in every-day language, and he does it so skilfully that it makes the reading even of complex physical explanations a matter of pure pleasure. He makes fun of popular fallacies, debunks widely held beliefs, and enlivens his explanations by highly characteristic and often amusing hand sketches. In short, he easily succeeds in holding the attention of the reader throughout an account which extends from the folk-lore of primitive people to an original theory of the sudden cloud-burst connected with the first lightning stroke of a heavy thunderstorm.

An historical review of ancient beliefs and myths, with particular reference to South African tribes, is followed by a description of striking examples of lightning damage to buildings and ships and the detailed story of Franklin's experiments culminating in the invention of the lightning conductor and its early application in Europe and America. In describing the various types of lightning flashes the author expresses a certain scepticism for popular accounts of ball lightning. He deals with the effect of lightning on buildings and trees, the colour of lightning, the frequency of thunderstorms and the sound of thunder.

The historical development of the Boys camera, which in Dr. Schonland's hands became the key to our modern knowledge of the lightning discharge, is described, and there follows a detailed analysis of the mechanism of the lightning discharge in its various stages. Some recent observations of the cell structure of thunderclouds gives the author a novel clue to the mechanism of multiple lightning-stroke flashes.

A further chapter is devoted to the protective effect of a lightning conductor and its range of protection, a subject which has remained of widely controversial nature up to the present time, and on which Franklin's views appear to have been nearer the truth than those of many of his followers. Basic rules are given for the protection of buildings, human beings and livestock.

To the physically minded meteorologist it should be a challenge that, with all our present-day knowledge of the lightning discharge itself, the actual mechanism underlying the electrification of thunderclouds remains still unsolved. The author explains the various existing theories and shows their practical application in artificial rain-making.

The distant electrical effects of lightning discharges are examined with particular reference to the atmospherics which constitute the bane of radio reception, and which, from the author's investigations, led to new knowledge on the height of the reflecting ionospheric layer. The importance of this new knowledge for wireless communication and thunderstorm forecasting is underlined.

In the case of a book which gives the reader throughout as much pleasure as it clearly gave the author to write it, the reviewer hesitates to draw attention to slight shortcomings. Suffice it therefore to say that the author occasionally refers to the most frequent value of a parameter where the mean value is intended (e.g. charge in a lightning flash and amplitude of lightning current) and that he states that 10 per cent. of all strokes produce current amplitudes of less than 20,000 amp., whereas it is at least 50 per cent.

The book is excellently produced, and will, it is confidently expected, greatly increase the existing small circle of people who share the author's "passion for a flight of thunderbolts".

R. H. GOLDE

Australian drought cycles. By V. R. Aldis. *The Australian Surveyors*, June–Sept. 1949. pp. 16. Institution of Surveyors, Sydney, N.S.W.

The well defined trends in the Australian rainfall pattern are brought out by curves of the 3-year running means at stations with long records. It is shown that the periods of rain deficiency are spaced at intervals of about 15 years and, following the recently ended period of marked rainfall deficiency, the present prospect is stated to be a relatively increased rainfall during the next decade. At the same time it is admitted that " true mathematical periodicity undoubtedly does not exist " !

J. GLASSPOOLE

BOOKS RECEIVED

The general characteristics of squalls at Peshawar. By C. Ramaswamy and K. C. Majumdar. *Mem. India met. Dep., Delhi*, Vol. XXVIII, Pt. I. Size: 11¾ in. × 9¼ in., pp. 1–53, *Illus.* Manager of Publications, Delhi, 1950. Price: *Rs.* 7–8 or 11*s.* 6*d.*

Rainfall at Peshawar. By C. Ramaswamy and N. Suryanarayana. *Mem. India met. Dep., Delhi*, Vol. XXVIII, Pt. III. Size: 11¾ in. × 9¼ in., pp. 121–37, *Illus.* Manager of Publications, Delhi, 1950. Price: *Rs.* 3–6 or 5*s.* 6*d.*

Discussion on a method of predicting night minimum temperature in winter. By K. C. Chakravortty. *Sci. Notes India Met. Dep., Delhi*, Vol. XI, No. 135. Size: 10 in. × 7 in., pp. 39–46. Manager of Publications, Delhi, 1950. Price: *Rs.* 1–2 or 1*s.* 9d.

Annual Reports 1940, 1942, 1946 and 1947. Apia Observatory. Size: 9½ in. × 6 in. pp. iv+167, iv+166, ii+146 and ii+158. New Zealand Department of Scientific and Industrial Research, Wellington. Prices: 5*s.*, 5*s.*, 6*s.* and 6*s.*

Die Bestimmung de Komponenten der atmosphärischen Trübung aus Aktinometermessungen. By Walter Schüepp. *Archiv. Met. Geophys. Bioklimat.* B, **1**, 1949, pp. 259–346. Size: 9 in. × 6 in., *Illus.* Springer-Verlag, Vienna.

METEOROLOGICAL OFFICE NEWS

Forecasts for farmers.—During the harvest month of September, many inquiries from farmers were received by the forecasting offices listed in the Post Office Guide. Over 100 inquiries were dealt with at each of the following offices: Shawbury, Southampton, Gloucester, Upavon, Abingdon, Bawtry, Mildenhall and Mount Batten. The greatest demand was at Abingdon where 420 requests were received.

Letters received from County Secretaries of the National Farmers' Union have shown how much this service has been appreciated.

Ocean weather ships.—Service in ocean weather ships is voluntary and up to the present it has been possible to fill all the posts; indeed, the number of Assistants who have volunteered has been more than was needed. However, additional officer volunteers are now required—Assistant Experimental Officers in particular. All who are interested are invited to send their names to the Director (M.O.10).

Living accommodation at R.A.F. stations.—Staff will be glad to learn that a house is to be provided for a meteorologist at some 40 permanent Royal Air Force stations in this country at which 24-hour rosters are not worked but staff are liable to be called upon for duty outside normal hours.

R.A.F.V.R. Meteorological Section.—A programme of continuous training for the year 1950 carried on well into October. About 25 per cent. of the total strength of the section took their continuous training during the period of the R.A.F. Autumn Air Defence exercise.

During the recruiting drive at the September meeting of the R.A.F. Meteorological Association, it came to light that many potential recruits had refrained from volunteering for the Meteorological Section of the R.A.F.V.R. in the belief that training would make greater demands upon them than they would be able to meet. The prevailing impression seemed to be that " non-continuous " training (week-ends and evenings) would take the form of a series of short lectures necessitating many attendances over the year. In fact, non-continuous training is performed mainly at the forecaster's desk where comparatively few periods of practical work make up the prescribed 90 hours non-continuous training per annum.

Obituary.—Staff who have served at Kew Observatory will learn with regret of the death on November 11, 1950, of Mr. Bertram Francis at the age of 70. He was a member of the staff of the Observatory when it was taken over by the Meteorological Office in 1910, and remained there until his retirement in 1945.

Sports activities.—Facing p. 357 is a photograph of the trophies at present held by the Meteorological Office. In addition to these, six individual challenge cups are held by members of the staff.

Contributions to *Meteorological Office News*, which should be brief, will be welcomed. New uses for meteorological information, unusual personal experiences, and activities or achievements of staff are subjects of interest to readers.

WEATHER OF OCTOBER 1950

Mean pressure was between 1020 and 1022 mb. around the Azores, over the Bay of Biscay, central France and central Europe, and between 1015 and 1019 mb. over the eastern half of the United States and in Quebec. It was below 1000 mb. south-westward of Iceland, and below 1005 mb. in western Alaska and the Aleutian Islands.

Over nearly the whole of Europe, and most of the Mediterranean, it was slightly above the average for October. The excess amounting to 5 mb. over part of northern France. South-westward of Iceland, however, there was a deficit of more than 5 mb. Over most of North America mean pressure was slightly below the average, the deficit exceeding 5 mb. in Idaho, the west of Montana and states further west, and in British Columbia.

In the British Isles, the month was dry in the east and south but rainfall exceeded the average on the whole in the north-west.

The tracks of the main depressions were almost all to the north of the British Isles. In the opening days a depression moved north-east across north Scotland causing rain or showers generally, with somewhat widespread thunderstorms in England and Wales. On the following days a very deep Atlantic depression moved north-north-east to the south of Iceland and an associated trough crossed the British Isles; heavy rain fell in the north-west on the 3rd but little or none occurred in eastern and midland districts of England (3·76 in. at Glenquoich and 2·81 in. at Kinlochourin, both in Inverness-shire). The 5th in particular, was a warm, sunny day in most areas, temperatures reaching 70°F. at a large number of places in England and touching 75°F. in London, at Camden Square. On the 6th and 7th another Atlantic depression approached the Faeroes and then turned north-north-east, while a trough crossed the British Isles causing showers in western districts; on the 8th a cold front, moving east, was associated with widespread thunderstorms in the northern half of the country. Thereafter a depression north-west of Scotland moved a little north-east and then turned east along our northern seaboard; rain fell generally on the 9th mainly slight in the east of Great Britain but heavy, with local thunderstorms, in the north-west (2·13 in. at Glencoe, Argyll). Subsequently a ridge of high pressure moved east over the British Isles and combined with an anticyclone over northern Scandinavia; a mainly fair day, with good records of bright sunshine was experienced in Great Britain on the 11th but more rain occurred later in Scotland and Northern Ireland. A deep Atlantic depression moved north-east to Thorshavn from the 12th to the 14th causing further rain, chiefly in the north and west, though slight rain occurred in eastern England also on the 13th. On the 16th a trough of low pressure off our western seaboard moved east and heavy rain was registered in the north-west (1·75 in. at Glenbranter, Argyll, and 1·38 in. at Ambleside). Local gales occurred rather frequently at exposed places in the north-west and north during the first 17 days.

Subsequently the Azores anticyclone moved north-east and later a ridge of high pressure moved in over Scotland from the west. Anticyclonic conditions prevailed for the most part from the 18th to the 20th, with appreciable fog, particularly in England and Wales, on the 19th and 20th. On the 21st and 22nd the anticyclone moved east to southern Scandinavia and Denmark, while a trough of low pressure moved in over our western districts giving further rain there. Subsequently another anticyclone off the west of Ireland moved north-east to southern Scandinavia and a dry spell set in, which lasted until the 25th. In the rear of the anticyclone a slow-moving, shallow trough, associated with a depression off south-west Iceland, moved over the British Isles and caused rain or showers in many places. On the 29th a depression over Holland, moving irregularly south-east, was associated with showers in eastern England. In the closing days of the month troughs of low pressure moved east over the British Isles. Rain, rather heavy in places, fell on the 30th and scattered rain or showers, chiefly in the west, on the 31st. The last week was cold and unusually low minimum temperatures for the season occurred, particularly from the 27th to the 29th (20°F. at Porton on the 28th and 18°F. at Dalwhinnie on the 29th); fog was also widespread at times.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	75	21	0·0	44	−6	100
Scotland	66	18	+0·2	98	0	98
Northern Ireland ...	64	27	+0·3	108	+2	98

RAINFALL OF OCTOBER 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	·41	16	*Glam.*	Cardiff, Penylan ...	1·78	37
Kent	Folkestone, Cherry Gdn.	1·01	25	*Pemb.*	St. Ann's Head ...	...	...
„	Edenbridge, Falconhurst	·18	5	*Card.*	Aberystwyth	3·45	83
Sussex	Compton, Compton Ho.	·84	18	*Radnor*	Tyrmynydd	3·54	54
„	Worthing, Beach Ho. Pk.	·69	19	*Mont.*	Lake Vyrnwy	5·01	86
Hants.	Ventnor, Roy. Nat. Hos.	1·07	27	*Mer.*	Blaenau Festiniog ...	11·66	114
„	Bournemouth	·83	19	*Carn.*	Llandudno	2·56	76
„	Sherborne St. John ...	·44	13	*Angl.*	Llanerchymedd ...	3·83	85
Herts.	Royston, Therfield Rec.	·41	15	*I. Man*	Douglas, Borough Cem.	4·18	92
Bucks.	Slough, Upton	·48	17	*Wigtown*	Port William, Monreith	3·60	91
Oxford	Oxford, Radcliffe ...	·50	17	*Dumf.*	Dumfries, Crichton R.I.	2·55	65
N'hants.	Wellingboro', Swanspool	·60	24	„	Eskdalemuir Obsy. ...	4·66	86
Essex	Shoeburyness	·26	11	*Roxb.*	Kelso, Floors	1·50	52
„	Dovercourt	·31	13	*Peebles*	Stobo Castle	2·91	84
Suffolk	Lowestoft Sec. School ...	1·24	44	*Berwick*	Marchmont House ...	1·69	44
„	Bury St. Ed., Westley H.	·47	17	*E. Loth.*	North Berwick Res. ...	1·71	58
Norfolk	Sandringham Ho. Gdns.	1·36	45	*Midl'n.*	Edinburgh, Blackf'd. H.	2·07	76
Wilts.	Bishops Cannings ...	·83	25	*Lanark*	Hamilton W. W., T'nhill	3·13	96
Dorset	Creech Grange... ...	1·50	29	*Ayr*	Colmonell, Knockdolian	4·63	104
„	Beaminster, East St. ...	1·65	37	„	Glen Afton, Ayr San ...	5·15	101
Devon	Teignmouth, Den Gdns.	1·32	34	*Bute*	Rothesay, Ardencraig ...	7·35	167
„	Cullompton	2·06	50	*Argyll*	L. Sunart, Glenborrodale	...	...
„	Ilfracombe	2·17	48	„	Poltalloch	6·32	128
„	Okehampton, Uplands	1·93	32	„	Inveraray Castle ...	11·16	159
Cornwall	Bude, School House ...	2·30	57	„	Islay, Eallabus	7·04	148
„	Penzance, Morrab Gdns.	2·40	52	„	Tiree	6·90	151
„	St. Austell	2·61	50	*Kinross*	Loch Leven Sluice ...	3·02	88
„	Scilly, Tresco Abbey ...	2·64	69	*Fife*	Leuchars Airfield ...	1·58	61
Glos.	Cirencester	·86	26	*Perth*	Loch Dhu	9·32	130
Salop	Church Stretton ...	1·62	44	„	Crieff, Strathearn Hyd.	2·73	69
„	Cheswardine Hall ...	...	...	„	Pitlochry, Fincastle ...	2·31	71
Worcs.	Malvern, Free Library	·85	29	*Angus*	Montrose, Sunnyside ...	1·34	49
Warwick	Birmingham, Edgbaston	·79	28	*Aberd.*	Braemar	2·02	54
Leics.	Thornton Reservoir ...	·89	32	„	Dyce, Craibstone ...	2·02	60
Lincs.	Boston, Skirbeck ...	·93	34	„	Fyvie Castle	1·25	33
„	Skegness, Marine Gdns.	·97	35	*Moray*	Gordon Castle	1·08	34
Notts.	Mansfield, Carr Bank ...	·89	29	*Nairn*	Nairn, Achareidh ...	1·11	48
Derby	Buxton, Terrace Slopes	3·02	61	*Inverness*	Loch Ness, Garthbeg ...	4·10	115
Ches.	Bidston Observatory ...	2·00	61	„	Glenquoich	16·97	170
Lancs.	Manchester, Whit. Park	2·40	73	„	Fort William, Teviot ...	11·51	162
„	Stonyhurst College ...	3·84	86	„	Skye, Duntuilm ...	5·74	105
„	Squires Gate	2·57	73	*R. & C.*	Tain, Tarlogie House ...	1·58	57
Yorks.	Wakefield, Clarence Pk.	1·10	38	„	Inverbroom, Glackour ...	6·69	119
„	Hull, Pearson Park ...	1·10	37	„	Applecross Gardens ...	6·66	112
„	Felixkirk, Mt. St. John	1·10	38	„	Achnashellach	10·03	132
„	York Museum	1·20	45	„	Stornoway Airfield ...	4·37	89
„	Scarborough	1·23	39	*Suth.*	Loch More, Achfary ...	10·40	133
„	Middlesbrough... ...	1·00	33	*Caith.*	Wick Airfield	1·75	59
„	Baldersdale, Hury Res.	2·62	66	*Shetland*	Lerwick Observatory ...	6·13	155
Norl'd.	Newcastle, Leazes Pk....	·89	29	*Ferm.*	Crom Castle	2·98	92
„	Bellingham, High Green	2·70	69	*Armagh*	Armagh Observatory ...	3·63	133
„	Lilburn Tower Gdns. ...	1·74	47	*Down*	Seaforde	...	...
Cumb.	Geltsdale	3·02	81	*Antrim*	Aldergrove Airfield ...	2·71	90
„	Keswick, High Hill ...	5·66	101	„	Ballymena, Harryville...	3·51	95
„	Ravenglass, The Grove	3·26	75	*L'derry*	Garvagh, Moneydig ...	4·43	125
Mon.	Abergavenny, Larchfield	1·61	38	„	Londonderry, Creggan	4·30	117
Glam.	Ystalyfera, Wern House	5·17	75	*Tyrone*	Omagh, Edenfel ...	4·22	115